

A photograph of a tropical beach scene. In the foreground, there is a sandy beach with several palm trees and some thatched huts. The water is a deep blue, and there are some small boats or structures in the distance. The sky is clear and blue.

# Integrated Coastal Development Project Port of Angoche Mozambique

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# Integrated Coastal Development Project

Angoche, Mozambique

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## Preface

This report shows the results of a research project in Angoche Mozambique, which has been carried out within the framework of the Master Transport, Infrastructure and logistics and the Master Hydraulic and Geotechnical Engineering. It was a very interesting and diverse project, which is reflected by its research team. As team members we have a diverse background and all together we have an interesting view on the problems which occur in Angoche. In this report this view has been written down and at the end some recommendations concerning situation in Angoche are given.

A few people who deserve special thanks. Jaap de Kroes and Fansisco Mucanheia who initiated the project. Prof. Dr.Ir. M.J.F. Stive, Dr. Ir. P.J. Visser, Ir. K.G. Bezuyen and Dr. Ir. J.H. Baggen for their support and for sharing their knowledge. And we thank District Administrator, Mr. M. T. Braga and the Mayor, Mr. A. Assane for their hospitality. We also owe a lot of thanks to SNV Mozambique.

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We enjoyed the research and hope you will enjoy your reading.

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### Gerrit Heijkoop:

During the project my focus was on the Socio Economic System. Using past experience in actor- and network analysis and port planning, I learned something about the desirability and feasibility of the project. With insight in different problem perceptions, network relations and resources a cargo forecast is made. In the second phase I have focused on port administration and port layout.

### Ties van der Hoeven:

During the project in Mozambique, together with Marieke, I focused on the Coastal Morphology and on the dynamics of tides within and around the estuary. It was fun to use my creativity and my knowledge to look for good solutions for the problem in Angoche.

### Marieke Lely:

During the project in Mozambique, together with Ties, I focused on coastal morphology and on the dynamics of tides within and around the estuary of Angoche. I have really enjoyed this unique experience of spending some time in Africa 's hidden treasure, Mozambique.

### Tamara Duvivier:

At the moment I am busy with my master in Building Engineering. Although I prefer the 'dry' engineering, I didn't loose my interest in Hydraulic Engineering. During the project I focused on the port layout. Using my experience in functional design and my knowledge of construction, I came to the most efficient layout. I have really enjoyed my stay in Mozambique!



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## Summary

The analysis of the Socio-Economic system sets the engineering problems in a broader perspective. It answers why a technical problem should be solved and in what kind of socio-economic environment. An insight in recent history shows that Angoche once was an important port and town for the Nampula province. Agro-Industry was the main economic driver, producing cashew, sisal hemp, cotton, sugar and prawns. Civil strife, tragic World Bank policy and the development of the natural deep port of Nacala brought down the town and District of Angoche.

A deteriorated road and port put it on an 'infrastructural island', which holds back all economic activity, essential to solve everyday problems as immense unemployment, public health and education. Agro-Industry (namely cashew, cassava and fresh fish/prawns), tourism and exploitation of heavy sands (containing titanium) are defined as possible new economic drivers. All three can profit from an operational industrial port that opens a gateway to the international port of Nacala. The District Administration is chosen as the problem owner since it is responsible for the infrastructure in the District and its jurisdiction overlaps more or less the future possible hinterland of the port. Due to the Administration's budget, private investment is necessary to improve feasibility.

An actor and network analysis reveals that higher-level government is focussed on further development of Nacala (infrastructure) and Ilha de Moçambique (tourism). Getting them involved to formulate a consistent policy for Angoche in all relevant fields might be the biggest challenge. Three scenarios, using the three opportunities for the region, show that serious port development is only desirable when a large private investor can function as a driver for the whole region. In the two other scenarios focussing on the development of the road to Nampula seems more useful.

The North of Mozambique, and Angoche in particular, have an interesting natural environment. The tropical climate and the influence of the Indian ocean provide for an ecological system with a great biodiversity. Many people in Angoche work in the fishing industry and profit from the protection of the ecological system and a working port with a good connection to the open sea. In this research we have tried to solve the problem concerning navigability of the entrance of the channel, which leads to Porto de Angoche. In the paragraphs one to four, descriptions of North East Africa, the coastal region of Angoche, the estuary and its morphological system in particular give a clear image of the field of research. We are dealing with an estuary with a tide dominated (low) outer delta and a short tidal basin, vegetated by many mangrove forests. After analyzing the flow area we come to possible interventions which could provide a better entry to the port. On the basis the Multi Criteria Analyses, costs and the policy of the District of Angoche, these interventions are narrowed down to three best, most suitable solutions, which are: guiding of the ebbstream in combination of decrease of sediment in suspension (route II), submerged water wall (route I) and dredging. Because there are still a lot of uncertainties concerning the effects of the interventions, it is recommended to do more research when actual application is considered.



The takeover of Nacala as the main port for the province of Nampula has drastically put limits to the possible future hinterland for the port of Angoche. Along the approach channel, several locations can be distinguished where port activity, mostly fishery, is taking place on a small scale: *Porto Nova*, the new port since 1973, a *jetty*, constructed at the edge of town in 1991 and the *beaches* used for simple landing by local fishermen. The services provided at these locations are scarce. The main goal of the project is to design a functional port in Angoche, at the site with most potential for port development, comprising the required facilities. Based upon the criteria accessibility over land, conditions of the approach route over water, availability of facilities and the possibility of expansion, it can be concluded that *Porto Nova* has the most potential for port development. The key element of the port, namely the mooring, is in very poor condition and improvement of the mooring is priority number one.

In this report the scenario '*Gateway to Nacala*' will be further outlined. In order to allow vessels, with dimensions of the defined design ship ( $l \times w \times d = 90 \times 11 \times 4.5\text{m}$ ), to make use of the port, the spit of land needs to be extended for 100 meters, up to the two meters depth line and has overall latitude of 40 meters. The design comes in combination with dredging: 3.5 meters is necessary to allow larger vessels to make use of the port.

Different types of waterfront structures are distinguished and criticized for the port of Angoche:

1. Piers: Jetty on piles; Floating pier with Access Bridge
2. Quay Walls: Gravity and pile supported walls; Caisson Structure; Block Structure; L-wall Structure; Pile supported wharves.

The choice of the appropriate construction is based upon its: Feasibility: availability of skills and equipment; Constructive qualities: strength and weaknesses of the structure; Durability/flexibility: bearing in mind the existing tendency to transship in containers. *The pile supported short pier* has been chosen, seeing the demand for durability and the presence of weak soil in the port area. The design of the short pier constitutes a timber deck supported by timber piles, constructed in the tropical hard wood OPEPE, due to its high availability, relatively low weight (advantage during construction) and relatively low costs. Heavy-duty cleats are used to accommodate the larger vessels; simpler mooring cleats for the smaller vessels. The total cost of the pile supported short pier is estimated on 800.000 euros.

Angoche is a very interesting study object in several scientific fields. Combining the insights of these studies shows that a lot of the possible measures and technical solutions are not yet relevant. Of the three constructed future scenarios, only the most progressive one, where a large private investor comes to the region, justifies large investment in port development and accessibility of the channel. However, investment in infrastructure is essential, but this can just as well be the road to Nampula. A further study into the choice between these modes of transport is recommended.





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# Part 1: Research Plan



# 1. Introduction

## 1.1. Case description

Wherever land, water and human settlements meet, interesting issues arise. The principle of Coastal Zone Management deals with these issues. Integrated coastal zone management involves the comprehensive assessment, setting of objectives, planning and management of coastal systems and resources, taking into account traditional, cultural and historical perspectives and conflicting interests and uses. There is a distinction between the socio economic (human) system and the natural system.

This report deals with the Integrated Coastal Development Project in Angoche, a little town in the north of the Nampula province. Angoche (formerly known as António Enes) is an old Muslim trading centre, dating from at least the 15th century. It was one of the earliest settlements in Mozambique and an important gold and ivory coastal trading post. During the early 20<sup>th</sup> century the Portuguese colonised the port and left in 1975 again. After the liberation the country entered a long phase of instability, during which the port of Angoche was neglected. Slow deterioration followed. In the natural system the population of Angoche, which now turned to shrimp fishing, were also confronted with a problem. Their entrance, from the bay to the open sea was slowly closing of due to a growing siltation barrier. Soon larger ships could only enter at high water, and when the current situation is not changed, the accessibility of the port is at stake.

Since the elections of 1994 Mozambique is working on a new future. Mozambique's development program is centred on project implementation, particularly in the field of local governance (decentralisation). The Integrated Coastal Development Project is part of this program. The project aims to give the local government of the District of Angoche an advice about the possible development of the port of Angoche. The development of this port could bring economical and social growth to the District of Angoche.

## 1.2. Problem definition

The port of Angoche, in the North of Mozambique has deteriorated. Recently, the port is slowly closing of from the sea due to a growing siltation barrier in the mouth of its estuary. When the time comes that even the small boats of the local fishermen cannot leave or enter the port anymore, the situation poses a direct humanitarian threat to the region of Angoche.

Structural measures to keep the port accessible will not only benefit the local community but can possibly induce an impulse to economic development in the whole region of Nampula.

## 1.3. Goals of the project

The main goal of the project is to give an advice about the possible development of the port of Angoche. This goal can be divided into three parts. In the first place the project aims to collect reliable, up to date and sufficient information about the current situation. Next there will be searched for creative solutions to the problems in the socio economic and natural systems. A third important part is the transfer of the gained knowledge. These three parts will now be further described.

The first part of the project will focus on the necessity and possibilities to renovate and exploit the port of Angoche. An analysis of the economy in the region, the parties involved and available resources should give insight in possible future developments. In the natural system the dynamics of the coastal area are subject of study in order to gain insight in the cause of the siltation. After studying the hydrodynamics and coastal morphology in the estuary, more is known about tidal currents, sand transportation, sedimentation and dynamics of plates.

After analysis of the current situation the goal is to find creative, effective and feasible solutions to the problems in the socio economic and natural system. These solutions are bounded by restrictions and requirements found in the exploration phase. The proposed measures will be judged on effectiveness, technical complexity and costs.

The findings in both the socio economic as the natural analysis, will be combined in an integrated plan. The acquired knowledge will be transferred to all involved and interested parties. They can continue the project with either further research or concrete actions. The results of the project will be given to parties on different levels; local, for example to the port administration and the mayor of Angoche; regional, to the governor of Nampula, who has ports with similar problems in his province, national; to the ministry of Transport and Communication who try to improve coastal infrastructure along the whole coast of Mozambique; and international, to developing organizations or companies in the hydraulic engineering field.



#### 1.4. Research question

The problem definition and project goals can be translated into a research question, which the project group will try to answer. This research question is:

*Is a durable development of the port of Angoche desirable and possible? And what measures can be taken to achieve this?*

To answer this question, the research is divided into two parts. One part focuses on the natural system: the estuary in the coast of Angoche, which copes with a severe siltation problem. This research will focus on gaining insight in the characteristics of this particular estuary and the causes of the siltation. Thereafter three measures will be further investigated for suitability: periodically dredging, guiding the ebb stream or changing the tidal prism to keep the approach channel accessible in a natural way.

The second part of the research will focus on the socio economic system. First the relation of Angoche to the hinterland and other ports will be investigated. From this information a cargo forecast is derived. Combining the forecast with queuing theory will pose demands and restrictions on the dimensions of port and approach channel. A possible port layout will be designed and an advice on port administration will be given.

All the gained insights will be combined into an integrated coastal development plan to answer the research question.

## 2. Development cooperation

This project is related to two major developments in Mozambique and is therefore of great importance for many party's. These developments are the decentralization and the development of the less prosperous North. In October 1994, the country held its first multi-party elections, and with success. Ever since the country has focused on reformation in political authority and recovery of the economy. The main point of the reformation in the political authority is the decentralization of it. The economic recovery focuses on the spread of prosperity from the more developed south to the more isolated north.

In this frame the local government of the province Nampula has initiated the idea to improve the estuary of Angoche by recovering its navigability. The attempted outcome is an exploitable port. The initiators of this project are the governor of Nampula, his assistant and the mayor of the town Angoche. The assistant of the governor, Mr. Francisco Mucanheia, has consulted the Netherlands in order to get the needed advice. On recommendation of the Delft Management Centre for International Cooperation (CICAT), the Universidade Mussa Bin Bique, the university in Nampula, has been contacted and they support the project. Furthermore the project group has contacted the university in Maputo, the Ministry of Transport and Communication and the port authority in Maputo.

Mozambique is one out of the 36 developing countries of which the Netherlands maintains structural bilateral aid relations. Therefore many Dutch organizations are involved, and have the support of the Ministry of Development Cooperation. The decentralization, the local approach of infrastructural projects and the conveying of knowledge, are the centre of attention of many organizations. Their main goal is to reduce the poverty and to stimulate the economy. However they do not cooperate sufficiently. For that reason the project group aims to connect the several involved organizations so that all involved parties achieve the desired information and knowledge. The group has already contacted the developing organization SNV.

### 3. Description of country, region and town

#### 3.1. Mozambique

##### *History*

The Portuguese involvement began in 1498 when Vasco da Gama landed in Mozambique on route to India. Within a decade, the Portuguese had established a permanent settlement. The Portuguese lived of slavery, agricultural estates and the concessions on products for South Africa coming from Rhodesia. The Portuguese control was old fashioned and cruel. The resistance movement Frelimo had to fight for more than ten years in order to gain the dependency in 1975.

##### *Politics*

In 1994 the first free elections were held in Mozambique. The president of Frelimo, Chinasso, won the elections closely followed by Renamo leader Dhlakama. Before these elections, the Renamo rebels managed to dislocate the Frelimo government. A time of violence, chaos and refugees followed. In 1992 the disarmament and demobilisation took place and Renamo became a political party.

##### *Economy*

Mozambique is one of the poorest countries of the world. When the Portuguese pulled out, they left the country in a state of chaos with few skilled professionals and virtually no infrastructure. Moreover many destroyed their company they had to desolate. By the early 1990s, Frelimo had disavowed its Marxist ideology, announcing that Mozambique would switch to a market economy. Together with the terror of Renamo it caused the economical collapse of the country.

##### *Facts and numbers*

Official name:	Républica de Moçambique
Location:	Between 10 30° and 27° SL, and 30 30 ° and 41° EL
Surface area:	801 590 km <sup>2</sup> , of which is 21 371 km <sup>2</sup> inland waterway (22 times The Netherlands)
Provinces:	10 provincias; the capital is sometimes regarded as an 11th province
Capital:	Maputo, 1.070.000 residents
Infrastructure:	Road network in 1991: 27.287 km <sup>2</sup> , of which 4693 km <sup>2</sup> paved.

	Railway network of Empresa Nacional dos Caminhos de Ferro de Moçambique.
Ports:	Maputo-Matola, Beira, Nacala, Pemba, Quelimane, Inhambane.
Airports:	Maputo, Beira, Moçambique.
Population (1993):	19 916 000; Population growth increases with 2,7% /year
Population density:	21 residents / km <sup>2</sup>
Fertility:	6.5 children / woman
Birth rate:	45 / 1000 residents.
Death rate:	21 / 1000 residents
Infant death rate:	± 200 / 1000 residents
Life expectancy:	male/female is 45/43 years.
Illiteracy:	67% (female 79%)

#### 3.2. Province Nampula

Nampula was originally viewed as a vast hinterland to the more important Ilha de Moçambique and other Muslim trading settlements along the coast. The architectural cohesiveness of Ilha de Moçambique is one of its most important characteristics, and is one of the reasons why the island was designated a Unesco World Heritage Site. Originally inhabited by the Arabians and later, under the Portuguese control, it has assumed the role as the capital of Portuguese East Africa. Nampula moved into prominence in the early 20th century with the construction of a railway link from the coast westwards into Niassa province and the opening of the natural deep port at Nacala. Today, Nampula is Mozambique's second most populous province behind Zambezia, a productive agricultural area and the region's economic engine, though agricultural potential is hampered by weak infrastructure in many areas. Major crops include cashew nuts and cotton. The area is also rich in minerals and semiprecious stones, though these resources are under-exploited. The capital of the province, also called Nampula, is the commercial centre of the north.

##### *Facts and numbers of Nampula*

Location:	Nampula borders on the provinces Cabo Delgado and Niassa in the north, the province Zambezia in the south-west and the Indian Ocean in the east.
Surface area:	78.197 km <sup>2</sup>
Population:	2.974.486



### 3.3. Angoche

Angoche (formerly António Ennes) is an old Muslim trading centre dating from at least the 15th century. It was one of the earliest settlements in Mozambique and an important gold and ivory trading post. By the late 16th century, it has been eclipsed by Quelimane as an entry port to the interior. However, Angoche continued to play a role in coastal trade and was an important economic and political centre in the region, with close ties to Ilha de Moçambique. In the 19th century, Angoche became the focus of the clandestine slave trade, which continued until the 1860s when the town was attacked by the Portuguese. While effective Portuguese administration was not established until several decades later, the attack marked the beginning of Angoche's downfall, and the town never regained its former status.

Today, Angoche is a quiet, somewhat dilapidated district capital with few reminders of its past. North of Angoche is an attractive beach and stretching well south of town is a string of offshore islands. The residents live mostly of the fishery.

## 4. Theoretical background

The essence of the integrated coastal development project is based on 'coastal zone management'. The objective of coastal zone management is to successfully integrate the socio economic system and the natural system of a region. The socio economic system consists of the network of party's involved, future economic development and port planning issues. In this case the issues concerning the natural system are dominated by the dynamics of the estuary. In this chapter the relevant theoretical backgrounds of these systems are briefly discussed.

### 4.1. Socio economic system

For the analysis of the socio economic system four scientific concepts are relevant:

#### *Actor- and network analysis*

The complexity of a multi actor problem is mainly caused by the fact that every actor has his own interests, goals and perception of a problem. An actor has its own interpretation of causalities and can have a very different valuation of certain effects compared to another actor. Interests are defined by the whole set of values and preferences of an actor, independent of a specific situation. In relation to a certain problem, an actor formulates his goals as a derivation from his interests. By using a actor- and network analysis, similarities and differences in problem perceptions, goals and interests are located.

When exploring a complex technological problem it is important to gain insight in these different perceptions. In the first place because this leads to a qualitative better problem analysis since different views will be considered. Furthermore an analysis that describes positions, stakes, resources and relations will provide insight in possible threats or opportunities in the implementation phase. An analysis in which all actors involved are recognized and heard can count on more support.

The network analysis focuses on the relations between actors. Special attention is given to interdependencies between actors themselves and between actors and their environment. First of all dependence of a certain actor to a resource is considered. After that, the level of involvement of the different actors is addressed. In the end all findings are combined to see where problem perceptions, goals or interests correspond or differ. These conclusions will help to find a probable solution.



### *Cargo forecasts*

The forecasting process starts with the definition of the port's hinterland. Then the following steps will be taken:

- Assessment of economic and industrial development of the hinterland for different scenarios: positive, medium or no growth.
- Translation of the results into trade flows, both incoming and outgoing cargoes. This can be derived from the difference of production and consumption within the hinterland. The latter is extrapolated on the basis of economic parameters, such as growth of Gross Domestic Product (GDP).
- Potential shifts in cargo flows are investigated, caused by external influences.
- The last step is to analyse the different routing options that exist and all combinations of origin and destination. Here plays the issue of several ports serving the same hinterland, thus competition, an important role.

### *Design-ship*

Once there is some insight in possible trade flows and commodity groups, the volumes of cargo are estimated which will be transported over sea and an assessment is made of the type of shipping and the ship sizes. When addressing ship size, it is very important to consider the ships that currently sail the short-sea connections. Expected ship size is translated into measurements of the draught, beam and Length Over All (LOA) of a design-ship. These parameters pose demands and restrictions on the approach channel, port layout and operational efficiency.

### *Queuing theory*

Finally queuing theory is used to design a port layout and approach channel. From the cargo forecast an estimation can be made of the possible number of arrivals of ships. The actor analysis should reveal the operational demands of the port. What are available resources? What is the estimated service time (mooring, (un-)loading and administration)? What is the accepted waiting time? Using these parameters with the queuing theory gives the average waiting time and number of berths needed. This has consequences for the width of the approach channel and the port-layout.

### *Port administration*

Worldwide one can distinguish three different forms of organisation of public ports:

- Service Port: the port authority provides all services, including cargo handling and storage. This form was common in old times and can still be found in some developing countries. It is often characterised by bureaucracy and can only survive in case of a natural hinterland without competition of other ports.
- Tool port: the port authority remains responsible for providing the main ship-to-shore handling equipment (suprastructure), while cargo handling is carried out by private companies under licenses given by the port authority.
- Landlord Port: the port authority owns the land and gives concessions to private sector companies for provision of cargo handling and storage services. The port authority is responsible for the infrastructure, the nautical safety and access, including the maintenance of approach channel and basins.

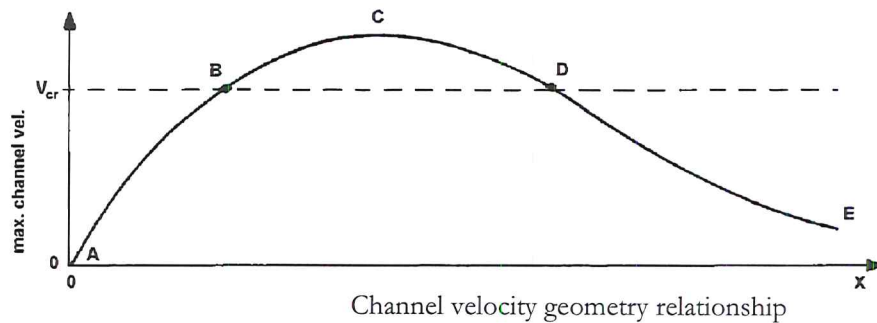
## **4.2. Natural system**

As mentioned earlier the dynamics of the estuary deserve special attention because of its relation to the causes of the problem. There is one scientific model that is very suitable to provide insight in the dynamics and the effectiveness of proposed measures.

### *Stability of the equilibrium condition by Escoffier*

The dynamic tidal inlet is governed by important factors, such as: tidal currents, extreme wind conditions, the tidal prism and littoral sediment transport. One way to study the dynamics is to find the relationship between channel velocity and geometry. The maximum channel velocity ( $V_m$ ) for the given estuary is function of the hydraulic radius of the channel ( $R$ ), its cross sectional area ( $A$ ) and the tidal range in the estuary ( $\Delta h$ ). Since this calculation is made for a given estuary, other variables such as channel bed roughness, its length, the surface area of the estuary and the tidal range at the sea, have become more or less constant.

Escoffier (1940) studied the stability of tidal inlets. He combined the variables for a given estuary into a single parameter,  $x$ , such that a larger entrance cross-section results into a larger value of  $x$ . The relationship he found between  $V_m$  and the parameter  $x$  is shown in the figure below. The channel velocity at point B and D is called the critical maximum velocity, below which the velocity is too low to cause erosion. Point D represents a stable situation; the stable equilibrium condition of the estuary.



## 5. Possible solutions

After the phase of exploration, where sufficient knowledge about both the socio economic and natural system is collected, it is time to use creativity. In this project the following concepts will be subject of investigation:

### 5.1. Socio economic system

In the socio economic system an assessment of the following issues will be made:

#### *Port layout*

After different planning elements are defined, they must be pieced together in a layout. Several layouts in fact, because there are many different solutions possible. While the planning elements have to be determined on the basis of formal design rules or guidelines, making the layout does not follow formal rules. Though two important design concepts should be kept in mind:

- There should be no berths or hard structures in the stopping line of the vessels, also not beyond the turning circle. In case stopping manoeuvre fails, the vessel should be able to run aground in a soft bank.
- Terminals that produce negative environmental effects should always be placed downwind from other port activities and certainly urban areas.

#### *Port administration*

From the actor- and network analysis and consulting other ports in the country, there will be given an advice about the most suitable organisation of the port of Angoche. In order to do so, the organisation of public administration and the availability of financial resources should be considered.

### 5.2. Natural system

When searching for solution in the natural system an interesting point should be considered. As mentioned in paragraph 3.3, Angoche once played an important role in coastal trade and was an economical and political centre in the region, with close ties to Ilha de Moçambique. These historical facts imply that Angoche once had a functional port with a navigable entrance channel. So something must have caused changes in the geometry of the estuary over



time. Important to know before thinking of solutions is: what are the causes of these changes?

When comparing the old hydrographical map (mapnr. 2933) and the new one (mapnr. 2936) it could be a plausible theory that the mangroves have been cut down in the past to establish aquaculture. This could have reduced the surface area and the tidal prism. A smaller tidal prism brings the estuary in a new equilibrium state with a smaller equilibrium minimum cross section, which, in this case, means a shallower channel. Other possible causes are changes in the outflow of the river, changes elsewhere along the east coast of Africa or natural, evolutionary changes in long shore sand transport.

Depending on which causes result from a profound research one could think of the following technical measures:

- Enlargement of the tidal prism by changing the surface area: When changing the surface area, thus changing the tidal prism, one also changes the volume of water that enters and leaves through the tidal channel. The tidal basin and the tidal channel will have to store this extra water. The tidal basin can store the water widthways, spread over the enlarged surface area, on top of its flats. While the surface area of the channel stays unchanged water can be stored by deepening the channel by erosion.
- Guidance of the ebb stream (for instance by constructing groynes): By guiding the ebb stream in the outer delta one reduces energy losses, while transport capacity is increased. Thus erosion will occur and the channel will become deeper.
- Dredging: By dredging, the channel will be deepened artificially. The dredging process can be split up in four sub-processes, i.e.: Digging (breaking up the cohesion of the soil), Vertical transport, Horizontal transport and Deposition. Dredging equipment is often classified according to its mobility (stationary vs. non-stationary) and according to one aspect of the dredging process (i.e. suction dredge). Possible dredging equipments: trailing suction hopper dredges, cutter suction dredges, stationary plain suction dredge or dredging by creating a density current. Required capacity, restrictions to sizes and costs will determine which equipment to use.

## 6. Study objects, research methods and techniques

This chapter describes the specific subjects that will be studied and what kind of research methods and techniques will be used in order to gain information to answer the research question. For this research the following methodical construction will be used:

- Preliminary research
- Interviews
- Field-research
- Modelling
- Feedback

These steps do not have to be strictly executed in this order. The research will be an iterative cycle process, which shall be followed several times.

### 6.1. Preliminary research

Before carrying out the project, relevant available data will be collected. Hereby one tries to get an idea of how the present situation looks like. This pre-search takes place at home, in the Netherlands, as well as in Mozambique. At home the following sources are used:

- Books and papers related to the topic of the project, found in the TU Delft Library and in the African study centre in Leiden
- Reports of projects of reference, such as the project: *Survey in the port of Beira*.
- Meetings with professors at the Technical University of Delft and University of Wageningen about their ideas concerning the problem in Angoche
- Up-to-date hydrographical maps. With these maps and the theoretical background a first estimation of the important parameters of the estuary can be made; e.g. when the stable equilibrium condition is reached?

It is found that the minimum equilibrium cross sectional area of the entrance is linearly related to the volume of the tidal prism:



$$A = 7.0 \times 10^{-5} * P$$

**A** = the minimum equilibrium cross section of the entrance channel (throat) measured below mean sea level in m<sup>2</sup>

**P** = the tidal prism volume in m<sup>3</sup>

$7.0 \times 10^{-5}$  = a reasonable constant for the estuary in Angoche

On the basis of a hydraugrafic map (mapnr. 2936) of the coastal region of Nampula province, the following calculation has been made for the tidal prism (**P**) and the minimum equilibrium crosssectional area (**A**) for the estuary:

Data derived from the hydrographical map:

Width channel = 3 km

Length channel = 20 km

Difference between MHW and MLW = 4 m

These values are assumed to be constant.

For the tidal prism **P** we find;

$$P = B * L * (MHW - MLW) \rightarrow P = 3 \times 10^3 * 20 \times 10^3 * 4 = 240 \times 10^6$$

This results in the following equilibrium minimum cross section **A**:

$$A = 7.0 \times 10^{-5} * 240 \times 10^6 = 16\,800 \text{ m}^2$$

When this is divided by the width of the channel we find for the channel depth:

$$h = 16\,800 / 3000 = 5.6 \text{ m.}$$

In Mozambique information is gained from the following sources:

- Documents found at Eduardo Mondlane University in Maputo
- Meetings with professors at the Eduardo Mondlane University in Maputo
- Hydrographical maps (perhaps less up-to-date), geological and geographical maps.
- Documents of and meetings with Ministry of Transportation and Communication. This can be especially be useful to make the cargo forecast. When the hinterland has to be defined, several questions have to be asked. What area can receive benefits of the possible development of the port? In what state are the

infrastructural networks that connect the port and the hinterland? Is there a supply or demand of goods for transportation and do they have a potential for growth in the future? These cargo flows can then be grouped into commodity groups according to economic and transportation characterisation.

- Documents of and meetings with people of the CFM (CFM owns the port of Angoche) and people of the MPDC (Maputo Port Development Company - the privatised consortium of the port of Maputo)
- Documents of and meeting with people of DNA (Direcção Nacional de Águas- National Directorate of Water)

## 6.2. Interviews

The preliminary research will give a good indication of the present situation and all the parties involved. Though, one can only know what really goes on if personal contact is made. Particularly when conducting the actor- and network analysis, in order to gain insight in the actor's problem perception, the following questions have to be answered:

- Which criteria does an actor use to judge the situation?
- What does the actor see as the core of the problem? How far are the current and the desired situation apart? What are the actor's system boundaries?
- How does the actor define the main causes of the problem?
- What means of influence or resources does the actor have in relation to the problem or its causes?

But also more in general talking to party's involved should give insight in:

- What happened with the port in the past
- Whether a functional and navigable port is desirable in Angoche.
- Whether a functional port could be profitable in Angoche or whether another location is desired.
- Whether available materials are sufficient.
- Whether local people are willing and able to participate in reconstructing the port or entry channel.
- Whether local government and companies are willing and able to participate in the implementation of the project.

### 6.3. Field research

The field research serves for checking the information gained from specialists and official documents and for adding relevant, missing information. Especially the data about the tidal range will be subject to investigation. This is because the specific conditions on the site (estuary) are expected to affect the overall tidal situation. One month of water level recordings is sufficient to determine tidal characteristics.

### 6.4. Modeling

To get a good insight in the pros and contras of the alternative solutions in the natural system a model will be used. The possible measures will be simulated with the ASMITA-model, developed at TU Delft under supervision of Prof. dr. ir. M.J.F. Stive. The reliability of results will be checked with handmade calculations. In addition to the possible measures mentioned above, combinations of the four measures will be looked at and will be simulated too.

The ASMITA-model is based on the following concept: geological timescales tidal basins can be considered as temporary, short-lived features. Their existence is the result of a complex interaction between the inherited morphology and substrate, sea-level variations and tidal motions, sediment availability and sediment distribution processes. On the timescales of their lifetime, say hundreds to thousands of years, it is assumed that their evolution can be understood or at least mimicked on the basis of the concept of accommodation space. This concept is based on the assumption that a tidal basin can reach an equilibrium volume relative to an invariable mean sea level. In this case accommodation space becomes zero because we consider the sea level rise to be zero. But this shows how far we can look in the future with this model, for example if we want to know what the consequence would be of some changes in the boundaries conditions, the ASMITA-model gives us predictions for a long term.

The model divides the tidal basin into three different parts. These are the channel, the flats and the outer delta. The proposed measures will be translated into model parameters and then the simulations can be run. The output of the model is the de- or increase of cubic metres sand in the three different parts. Combining the input and the output parameters we can obtain the new channel depths.

### 6.5. Feedback

While going through all different steps one should review once in a while. Reviewing in this case means return to relevant study material to see if in practise, theories are being followed within the concerning stage of the process. It also means return to plan of activity or previous stages in process to see if you're still in line with the main- and sub goals and if all requirements and restrictions are being taken into account.



## 7. Schedule

### *Arrival*

The arrival in Johannesburg (South Africa) is scheduled on the 6<sup>th</sup> of May. The next day we will leave for Maputo where several meetings are arranged.

### *Stay in Maputo*

It is expected that the stay in Maputo will be of great importance for the preparation of the research project and for the orientation of the project team. The project team will meet various people, who are, in their own specific way, interested in the project or who could provide us with some relevant information. The following meetings are planned:

- Meeting with the embassy
- Meeting with the head of Civil Engineering of Elduado Mondlane University in Maputo
- Meeting with some students of the Maputo University
- Meeting with people of the CFM and people of the MPDC
- Meeting with people of the Ministry of Transportation and Communication

Furthermore we will try to get hold of some relevant documents, reports and maps. At last the trip to the north is prepared in Maputo.

### *Trip to the north*

This trip is about 2000 kilometers. In a country with a surface area of 801 590 km<sup>2</sup> and only around 4000 km of paved roads the trip probably has to be done by plane.

### *Stay in Nampula (1)*

In Nampula, capital of the Nampula province, the University Mussa Bin Bique is situated. Since the initiation of the project there has been a frequent contact between Mussa Bin Bique University and the project team. In the city Nampula and at the university respectively the team will meet some influential people from the province as

well as professors and students. Together we will talk about the importance of the re-development of the port of Angoche. Furthermore information gained in Maputo will be evaluated In Nampula.

### *Field research in Angoche*

After a stay of 4 weeks we will finally get a chance of seeing the project area concerned. In Angoche the team will carry out the greatest part of its research. It's also in Angoche where the research will be completed and partly where knowledge and information will be handed over. The research is further described in chapter 6.

### *Stay in Nampula (2)*

After completion of the research, we will meet people of the Nampula province and Nampula University again to present and discuss the results. After the meeting the team can conclude the project and can present and hand over results of the project and relevant information to anyone concerned.

### *Come to conclusion*

After the last meeting in Nampula extra information/data will be added and results of the research, designs and advices will be ordered representatively.

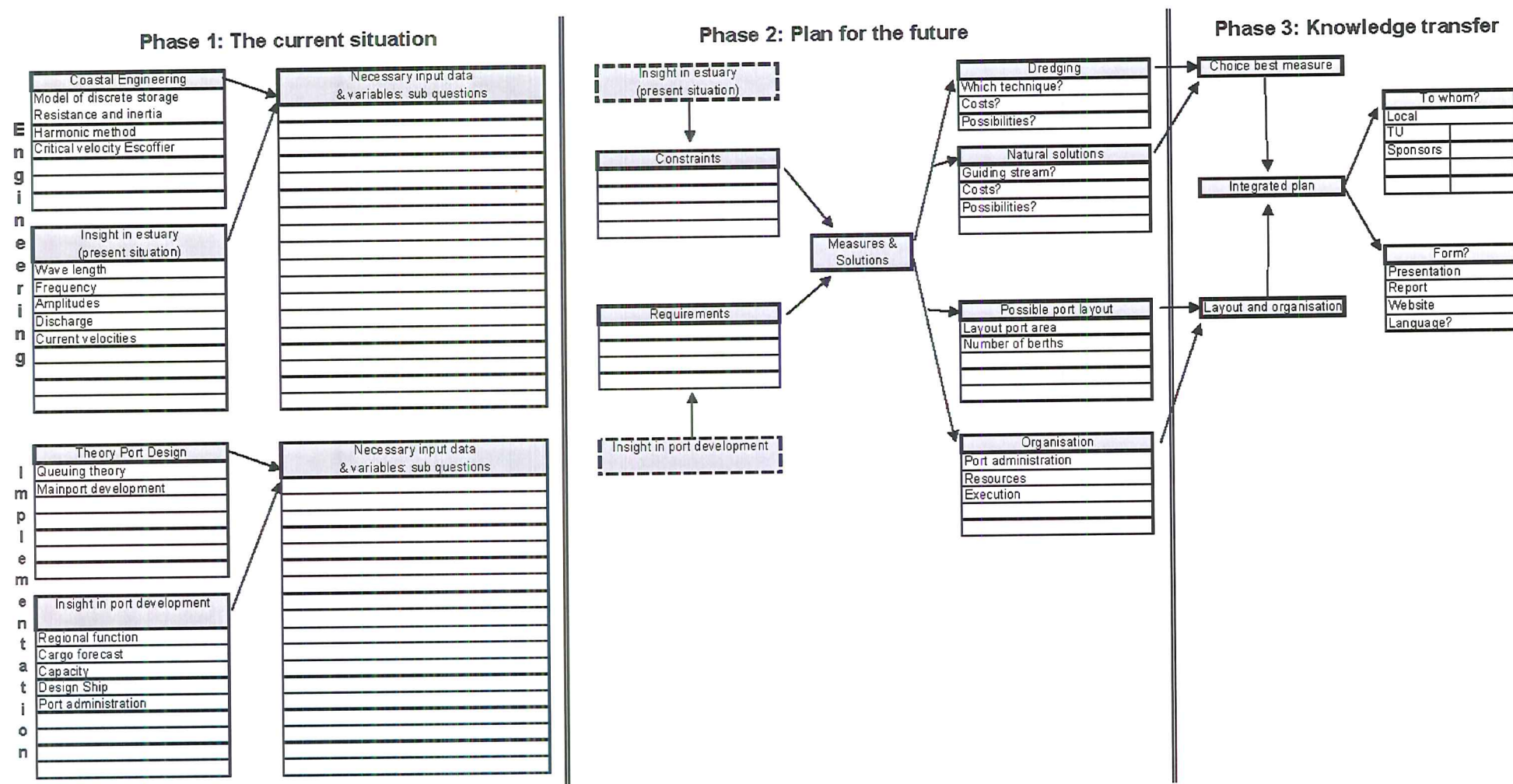
### *Handing over results/information*

Several parties have their own interest/influence in the project. Parties like (local) government, embassy, development organizations, students, professors, etc All parties deserve to know about the conclusions of the project. Only by handing over all facts, knowledge, know how and results the research can achieve its intensions.

Activity	week	May				June				July				August	
		19	20	21	22	23	24	25	26	27	28	29	30	31	32
Arrival															
Stay in Maputo															
Trip to the north															
Stay in Nampula (1)															
Field research in Angoche															
Stay in Nampula (2)															
Come to conclusions															
Handing over results/information															



## Graphical representation of research plan





## **Part 2: Socio Economic System**





# 1. Socio-Economic System

When considering the socio-economic system of the District of Angoche, the focus will be on social demographics and economic performance. Entering the city of Angoche, one can directly see history has laid a very heavy burden on the present situation. A drive around town and district leaves an impression of perished glorious days. Thus before analyzing the current situation, a brief insight of the historical developments is essential. This insight strengthens the system and problem analysis, which will be discussed in the following paragraphs.

## 1.1. Historical perspective

Angoche has been an important naval base for at least six centuries, mainly as a Muslim trading center, founded by Arabs coming down the Eastern coast of Africa. Somehow it always managed to possess a special position in comparison to the rest of the country, for example in the 1840's, when Angoche, due to its limited access for large vessels, was a hiding place for illegal slave traders. Later, the town was able to fight off the Portuguese occupation up till 1862 and was the last place in Mozambique to surrender. Finally occupied, the Portuguese always treated Angoche with delicacy and were never able to establish a strong colonial administration, which resulted into a relationship of mutual respect and cooperation.

In the 20<sup>th</sup> century the district was able to become a world player in the production and export of cashew nuts, sisal hemp, cotton, sugar and prawns. Raw cashew nuts have been exported from Mozambique since the beginning of the century, but when World War II hampered shipping to India, a local processing industry was born. In Angoche three large factories were built: Angocajú, Companhia Colonial de Antonio Enés and Companhia Colonial de Nacala. Production peaked in 1972 when Mozambique marketed 216.000 tons and the country was the world's leading exporter of shelled cashew (kernels).

Sisal hemp is a 60 - 100 cm long fiber from the sword-shaped leaves (leaf fiber) of the approximately 2-meter tall sisal agave (*Agave sisalana*). Due to its good resistance to moisture, sisal hemp is mainly used to produce cordage (ropes, binder twine etc.), brushes, sailcloth, tarpaulins, awnings, sacks and coarse woven fabrics. In the 70's there were over more than 40.000 acres of sisal hemp plantation in the district, mainly owned by a Swiss family. There were two large factories, one in Natir and one in Merrere.

Besides these main agricultural products, Angoche has always enjoyed world fame for its prawns and fresh fish. Artisan fishermen have always provided the larger share of the daily catch, but in the '60's and '70's some small-scale industries emerged. The accompanying ice factory made it able to export the prawns and shrimps all over the world. Fresh fish was mainly marketed in Mozambique.

Between 1960 and 1970 Angoche, in that time still called Antonio Enés, transformed from a village with no stone or concrete, into a town with surfaced, wide 'avenidas', Portuguese style, high rise apartment buildings and large villas. There were many stores, a supermarket and a cinema. Nightlife was sparkling with more than 17 bars and restaurants. The port was a center of activity and received at peak level more than 270 vessels per year. The large ships, about 4000 tons, moored in front of the Capitania in deeper waters



Bird's view of Angoche



Entering Angoche





Sisal hemp



Coconut plantation



Fresh fish

and were loaded and unloaded using over 100 smaller barges. At the quay the mostly 100kg bags were (un-) loaded by hand and passed on through a long line of men to the warehouses. In total 120.000 tons of cargo were handled by the port in those years. The roads were in relatively good condition and were used by many. There was still no tar or concrete road but the sand road was very well maintained. In this time Angoche functioned as the main port for the Nampula province.

## 1.2. The 'downfall'

Between 1970 and today, both António Enés and Mozambique have had a turbulent history. After independence in September 1974 several factors caused a total collapse of the Mozambican economy. Mozambique attained independence during the global depression that followed the 1973 Oil Crisis. This had not only a direct effect on the economy, but also caused the South African gold mines to lay off two-thirds of their Mozambican workers in 1976, leading to an immense loss in Mozambique's foreign earnings. Worse still, were the mass exodus of skilled Portuguese settlers and the related outflow of capital, which caused the collapse of many secondary industries within a year of independence. The new government tried to abate this outflow by nationalizing several industries, but at a pace that only caused the situation to spiral, and gave many Portuguese settlers a pretext for destroying anything they could not take out of the country. Even nature seemed to have turned against the liberated Mozambicans, since disastrous floods hit the main agricultural areas in 1977 and 1978, to be followed by four years of nationwide drought. In the 80's a centrally planned economic policy, focused solely on agriculture, particularly on the creation of large state owned farms and the effects of a civil war contributed to a further downfall of the little secondary industry that had survived. At the end of the decade industry had ground to almost a complete halt.

Of course the District of Angoche suffered from the same burdens as the whole nation. This meant for example that the Swiss family, that disliked the post-independence political climate, stopped the sisal agricultural products eventually ceased. After the peace agreement in 1992 the local economy slowly tried to get back on its feet. Production levels came back to supply the local markets, but never regained their international importance. Only fishery and the cashew industry seemed to have survived.

However for the local cashew industry, events took another devastating turn. The droughts, war and displacement, inconsistent policies towards the smallholder sector, as well as ageing and diseased trees seriously affected production. Furthermore the World Bank, in its 1995 country assistance program, laid down a tragic condition: in return for reducing Mozambique's public debt by two-thirds, it ordered the liberalization of the cashew trade. The World Bank and the International Monetary Fund demanded that the Mozambican government stripped the processing industry of protection. Schemes whereby peasants were obliged to sell their nuts to the local factories did not please the World Bank. It always justified its free trade arguments with the claim that liberalization would ensure a fairer price for the peasant producers. However, the peasants have no organization of their own. Cashew is not a plantation crop, and no farmers rely exclusively on cashew. Cashew is a supplementary crop, often picked by the children of peasant households. Hundreds of thousands of unorganized peasant households are in no condition to take



advantage of liberalization to push prices up. They do not have marketing mechanisms of their own and are entirely at the mercy of the traders. The practical result of liberalization has been to encourage the export of raw nuts to India, where they can be hand shelled. By 1997, the factories in Angoche were closed and about 4,500 jobs were lost. Although intense national debate led to a rising of tariffs on raw nuts in 1999, and a few small factories have picked up again, most factories have not yet reopened.

### 1.3. Angoche today

Angoche today probably looks a lot like Angoche in 1970, affected by a 34-year lack of maintenance, civil war and poor population. Potholes dominate the wide 'avenidas', stores are empty and a lot of buildings are ruined. There are a few stores, which only sell some imported consumer goods and the presence of fresh fruit and vegetables is limited. The nightlife consists of only one restaurant (O Pescador) and two bar-dancing's (Parque and Club Sporting). The city center leaves a desolate impression. About 75% of the approximately 65.000 residents are unemployed. Most industries in the district are still closed and the only sector that remains, is fishery. Most of the fish is still caught by artesian fishermen, although there are two small-scale industrial fishing companies. Since a couple of months one cashew factory (Miranda Cajú) is slowly picking up production and is exporting the nuts to Holland.

From an infrastructural view, Angoche is more or less an island. The road to Moma is closed due to the defective bridge over the Melúli River, which collapsed during a cyclone in 2002. The road to Nacala is in poor condition and not accessible for trucks. And even the only road left, the one to Nampula, is barely maintained and during the raining season, December until March, often not accessible. Over water the situation is not much better. The siltation in the entrance of the estuary will be further discussed in the description of the natural system, but the result is that at low sea level the maximum draught of a ship is about 2 meters. And even if a vessel reaches the port it will find a rusty, sunk ship that functions as a quay with no further facilities. Finally, Nacala has developed itself as an international harbor due to its natural depth. It has fully taken over the port function for Nampula province, and thereby drastically decreased the possible hinterland for the port of Angoche. It needs no further explanation that this situation poses heavy limitations on any possible economic development in the District.



Deteriorated buildings, Angoche



Shipwreck near the port of Angoche



## 2. System and problem analysis

The Integrated Coastal Development Project tries to answer whether durable redevelopment of the port of Angoche is desirable and possible. It is important to understand where the outcomes can be positioned in a larger system and what problem they aim to solve. This understanding will profit the system analysis, solution evaluation and possible future execution. In this case the system boundaries are set equal to the boundaries of the District Angoche. This has both an administrative and an infrastructural reason: the District Administration is the lowest, interdisciplinary governmental division and its jurisdiction is more or less overlapping with the possible new hinterland of the port. In the following paragraph the relevant relations within the system will be described.

### 2.1. System analysis

Mozambique is one of the poorest third-world development countries. This means that it still has to deal with a lot of basic problems like poor water supply, public health issues and lack of infrastructure. The government's main objective is to maintain and improve the quality of life of its inhabitants and therefore it has to deal with these issues. Although a large part of Mozambique's population still lives in great poverty, the country has a tremendous economic potential and as history has proven, this is more than true for the District of Angoche. In order to reduce poverty, local government can try to lower the level of unemployment in the district. Choosing this objective is advisable, since employment is very effective to fight poverty and future results are easy to measure for policy evaluation.

In order to create demand for labour in the district, development of economic activity has to be stimulated. To achieve this, it is most important to attract investors to the region, reinforce agricultural production and develop opportunities for tourism. The attractiveness of the region is defined by several variables such as: price of land, presence of resources, supply of labour, tax climate, presence of supply industry and the accessibility. Especially this last factor is a very large problem in the whole of Mozambique and the District of Angoche as well. At many places there is a lack of infrastructure and most existing infrastructure is in poor condition. As described before, Angoche is more or less an infrastructural island. This is caused by a lack of financial means for investments in infrastructure and low demand for transport. Either private investors, taxes gained through increased economic activity or donators, can generate the financial means needed to invest.

Within this system there are a few variables that can be influenced by (local) government. To increase the attractiveness of the region, one of the most important issues is to improve the accessibility of the region. This can either by creating new, or improving existing infrastructure, for example to upgrade, repair and maintain the roads to Nampula, Nacala and Moma. Since Nacala, due to its natural depth, has become the main international port in the region, another good option is to establish an overseas connection between Angoche and Nacala. In this way the port of Angoche can become a secondary or 'feeder' port of Nacala. To achieve this, investments should be directed to redevelop the port of Angoche. Besides that a tax



Women of Angoche



Closed down Cashew factory, Angoche



climate favorable to investors should be created. Tax legislation should be designed in a way that provides incentives to invest in infrastructure and labour intensive industry. In the long term, positive effects can be expected from investments in education. A future generation with a higher level of basic education will produce more entrepreneurs, better farmers and skilled managers.

A visual representation of this system, using a Causal Relation Diagram, can be found in appendix A. The variables are briefly described in appendix B.

### Spirals

When taking a closer look at the system, one can find four positive 'feedback loops'. These loops are orderly presented in appendix C. The presence of these loops predicts a high instability of the system because all loops can either enforce each other or, once events take a wrong turn, the system can easily get stuck in a vicious circle. The situation described in the "the Downfall" paragraph confirms this. Another aspect of these feedback loops is the presence of the, earlier mentioned, 'chicken-and-egg' problem; E.g. in Loop 1, economic activity, induced by investors, will provide the financial means to improve infrastructure. On the other hand, economic activity will only increase once the infrastructural situation is improved, for which, at the moment, no means are available. Therefore the big challenge for (local) government is to turn the tide and start the system to spiral up again.

## 2.2. Problem analysis

From the above system description it can be concluded that, in order to reach its objectives, local government has to try to spiral up the system again. To do so, it has five factors it can control in order to change the outcomes of the system (i.e. investments in the port, build roads, tax climate, education and attractions in the region). It should develop a policy in which all of these factors are considered and directed in the right direction to enforce each other.

In order to give any economic development a better perspective, the infrastructural situation in Angoche should be improved. This will directly improve the attractiveness of the region but also, as a secondary effect, strengthen the existing and emerging agricultural and industrial production. Also for tourism development and the attraction of supply industry, better infrastructure is essential. Therefore government has to invest in both the port and the access roads.

Considering investments in the port, three main issues will be answered in this report:

- *What can be the future logistical function of the port of Angoche?*
- *What can be done to improve its accessibility over water?*
- *What should a possible port layout and quay look like?*



Road to Nacala



Port of Angoche





Entering the District, Mogincual border



The port's 'administration office', Angoche

### 3. Actor and network analysis

For the scope of this project the District Administration is chosen as the 'Problem owner'. It has the responsibility to invest in infrastructure in the district and, as mentioned before, its jurisdiction more or less overlaps the possible future hinterland of the Port of Angoche. However, being the owner of the problem does not mean the District Administration has the capacity, financial means and power to solve the problem by itself. Because of this dependency on others, it is very useful to get an insight in the objectives, stakes and problem perceptions of other parties involved. In the first place because this leads to a qualitative better problem analysis since different views will be considered. Second, an analysis that describes positions, stakes, resources and relations provides insight in possible threats or opportunities in the implementation phase. An analysis in which all actors involved are recognized and heard can count on more support.

In the following paragraphs an actor and network analysis will be conducted using five sequential steps: Problem definition as starting point, inventory of parties involved, inventory of perceptions, objectives and stakes, description of formal relations and mapping of dependencies.

#### 3.1. Problem definition as a starting point

In order to answer the research questions, the assumption is made that the District Administration acknowledges the necessity to invest in the port. Therefore the following problem definition is stated as a starting point to use during the actor and network analysis:

*The economic development of the District of Angoche is held back due to an insufficient service level of its infrastructure. In order to improve this situation, an overseas connection with Nacala is desirable and therefore the port has to be re-developed. Besides that, durable measures need to be taken to make the port accessible for larger vessels than the current draught limitation of 2.0 meters at low tide. Since the Administration's budget does not allow this kind of large-scale investments, private parties have to participate.*

In this report several measures to enlarge the depth at the entrance of the estuary will be considered. Besides that a possible port and quay design will be presented. These measures and designs will be judged on effectiveness, costs and durability. This actor and network analysis can help with the formulation of this judgment.

#### 3.2. Inventory of parties involved

Different parties can become involved with a problem for different reasons. It all starts with the problem owner and the parties it directly depends on while trying to solve the problem. Besides that, parties who possess certain needed resources, parties who are in someway affected by possible solutions or parties who



somehow have a stake in resolving the problem can become involved. Finding all parties is an iterative process, which has to be repeated every time a problem definition is adjusted or possible solution is stated. A large part of the complexity of this problem is caused by the involvement of many parties, both in the public as in the private sector. In the public sector this is mainly caused by Mozambique's large amount of ministries (22 ministries, see appendix D) and the hierarchical division of power into national, province, district and municipal organs. This can cause both policymaking and execution to become sluggish and less comprehensible. Since public-private cooperation is desired, a lot of private parties also have to be considered as possible future investors. An overview of parties involved is listed in appendix E.

### 3.3. Inventory of perceptions, objectives and stakes

It is very likely that all actors involved do not share the same perception of the problem. Everyone is trying to achieve its own goals, in line with its stake and therefore defines the problem different. There does not exist one single problem definition that is absolutely true but comparing the different views can bring one closer to a final solution. In this section each problem perception will be systematically reviewed. Sometimes there were clear statements, like policy documents or websites to gather information, in other cases rational analysis is used. In order to get the necessary insights the following questions were answered:

- What is an actor's main stake or function of existence?
- Related to this problem, what goal does it try to achieve?
- What standard does this actor use to measure the current or new situation?
- What does the actor see as the core of the problem? What is the main difference between the current and the ideal situation?
- What causes these differences according to this actor?
- How and by using what means can this actor influence the problem situation?

The outcomes of this analysis are orderly presented in appendix F. Most problem definitions aim at the (re-)development, though the scope or system boundaries differ very much. Most actors focus on development on their own scale of influence, e.g. the national government on the country and Kenmare Resources on the region. Furthermore the 'classic' opposite between environmental protection and economic exploitation is present.

We can further categorize these actors on the properties 'dedication' and 'dependency'. The first one answers if an actor is directly affected by solving the stated problem, e.g. by costs, revenues or any other way. The second property gives insight in the dependency of the problem owner, here the District Administration, on the means of influence of another actor. The two most critical issues are port development and everything related to that, and private financial means. Using this, a table is constructed, which is presented in appendix G.



The District's administration, Angoche



Road transport of prawns, Pescanorte, Angoche



Nacala Port, a possible associate?



Users of the bay, Angoche

The role of the ministry council and the ministries is a difficult to determine. It is possible to re-develop the port without the intervention of higher governmental bodies. However, in order to make the investment work, all policies should be adjusted to each other. This requires the involvement of high-level government. In the end it could even lead to the appointment of some scarce public funds. Now, combining all findings we can construct a table that gives insight in the dependencies of the problem owner. The table predicts some likely reactions of actors in the environment to its problem definition and problem solving process. This can either be reason to change its problem formulation and goals or to consolidate the support and create alliances. The position of actors in the table is strongly influenced by the problem formulation of the problem owner. For the District administration of Angoche and its objective to construct a port with the help of private investors, we have constructed the table as follows:

	Dedicated actors		Non-dedicated actors	
	Critical actors	Non-critical actors	Critical actors	Non-critical actors
<i>Like-minded perceptions, stakes and goals</i>	Actors who are likely to participate and are potential allies.	Actors who are likely to participate and are potential allies.	Essential potential allies who are difficult to activate.	Actors who initially do not necessarily need to be involved.
<i>Opposite perceptions, stakes and goals</i>	Potential blockers of (certain) changes. (Biting dogs)	Potential critics of (certain) changes. (Barking dogs)	Potential blockers who will not get involved. (Sleeping dogs)	Actors who initially do not need attention.
	Dedicated actors		Non-dedicated actors	
	Critical actors	Non-critical actors	Critical actors	Non-critical actors
<i>Like-minded perceptions, stakes and goals</i>	Kenmare Resources PLC Municipality of Angoche INAHINA WWF CFM Industrial Fishing Companies Cashew processing industry	Nacala Corridor Corporation Coastal Shipping Companies	Ministry council Ministry of Transport and Communication Ministry of Fishery Ministry of Tourism Province administration of Nampula CPI Donators	IDPPE
<i>Opposite perceptions, stakes and goals</i>		Inhabitants of possible affected areas Artesian Fishing industry	Ministry of Environmental Issues	



Besides the information from the earlier mentioned analyses, a categorization in dedicated and non-dedicated actor is used. An actor is usually a dedicated actor when it is affected by the problem through actual costs or revenues. As mentioned before, Angoche is not a priority for the important public organizations on a higher level. They focus their efforts on Nacala as a port and Ilha de Moçambique for tourism development. A most difficult and important task will be to motivate these non-dedicated actors and get them involved. A very positive conclusion is that there are no critical and dedicated actors who have an opposite problem perception or goal.

### 3.4. Formal relations

Positions and relations of actors have both a formal and informal component. It is important to have insight in both in order to get a better understanding of the parties involved and the problem situation. Informal relations are very hard to find, prove and analyze. However, they are very much influenced, shaped and bounded by formal relations. Therefore an analysis is made of the formal relations between the presented parties.

### Policy making in Mozambique

In the years after independence, a completely new apparatus of public administration had to be implemented. There was not a lot of experience and knowledge about this subject present in the country. An effort was made to establish a central government in Maputo, based on a planned economy. However, Mozambique is a very large country (22 times the Netherlands) with poor infrastructure and communication. So, probably because policy never reached the population it was intended for and execution was impossible to control, this attempt to manage the country and economy failed.

In recent years, Mozambique has made a movement towards decentralization. This means power has been shifted from national government to lower administrative organs like province and district. The country is divided into nine provinces, which are further divided into Districts; e.g. Nampula Provinces has 17 districts. These districts are then organized by 'Postos administrativos', e.g. de District of Angoche has four: Angoche-Sede, Aúbe, Boila-Nametoria and Namaponda. The larger communities then also have a municipality to take care of local public issues, i.e. in Nampula provinces there are five: Angoche, Ilha de Moçambique, Monapo, Nacala Porto and Nampula. Also most ministries have a directorate at local level, i.e. in Angoche: Agriculture, Veterans, Culture, Education, Industry and trade, Justice, Youth and sports, Women and social security, Planning and finance, Public health, and Employment (11 out of 22).

The District has its own budget and the course of action for the coming years is determined by three different strategic development plans i.e. one with a scope of five years, the other with a scope of three years and the last with a scope of one year. The latter two are derived from the first one. Every local directorate of a ministry produces its own input for these plans. These specialized plans are then integrated by the technical staff of the District Administration into a concept strategic development plan for the next



Tourism: Ilha de Moçambique



Conshelo, June 24th, 2004, Angoche



Conshelo, June 24th, 2004, Angoche

five years. Next a “Conselho Consultivo do Distrito” is organized, which is an assembly of all thinkable organizations in the district. The concept plan is presented and can be criticized by all present. The following representatives were present at this meeting in June 2004:

- **District representatives:**
  - of Aúbe (10)
  - of Nametoria (11)
  - of Nameponda (12)
  - of Mutukuti (4)
- **Representatives of the public sector:**
  - Nampula Province
  - Public health
  - Education
  - Agriculture
  - Social security
  - Employment
  - Industry and trade
- **Finance**
- **Culture**
- **Register**
- **Police**
- **Maritime authority**
- **Water company**
- **Electricity company**
- **Telecommunications company**
- **IDDPE**
- **NGO representatives:**
  - SNV
  -
- **Representatives of the private sector:**
  - Florestal
  - Miranda Cajú
- **Other:**
  - Catholic community
  - Muslim community
  - Fremilo representative
- **Invited, not present:**
  - Mayor
  - Municipality
  - Renamo representative

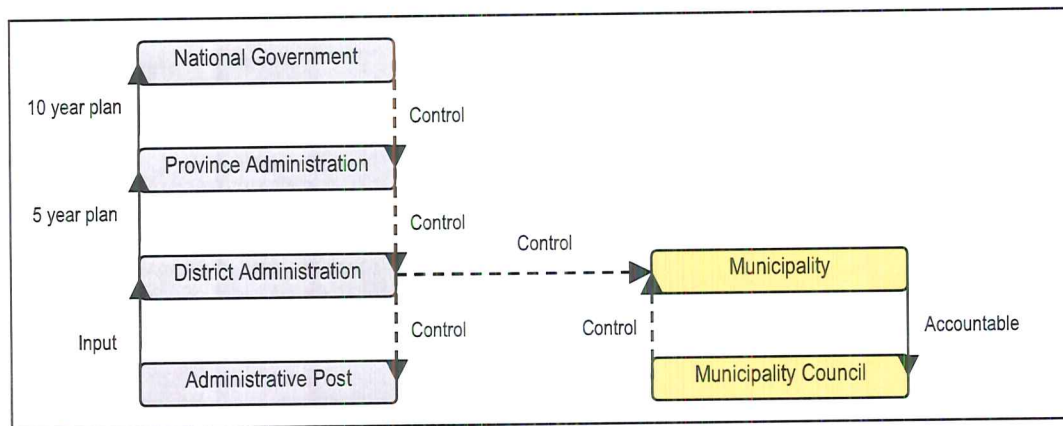
This feedback is used to make a final plan, which is handed over to the government of the Province Nampula. They integrate all plans from all districts and together with their own visions and objectives they develop a strategic development plan with a scope of ten years. This plan is then sent up to national government in Maputo, where the Ministry Council will decide on the course of action to be followed. This is then communicated downward to provinces, districts and directorates.

The municipality occupies an independent position in this system. It consists of an executive organ and a council with elected members that control it. The municipality has its own budget and can make its own policy, although in case this policy conflicts with the district policy, the District Administrator has the power to intervene. A graphic representation is given in the figure on the next page.



Electricity company, Angoche





### Re-development of the port

In Mozambique decisions on port planning are made by the central government in Maputo. It is under the responsibility of the Ministry of Transport and Communications and has to be approved by the Ministry Council. Since ports in Mozambique traditionally always have been Service ports, government also has the responsibility to provide and maintain the wet and dry infrastructure, the superstructure and labor. This is executed by INAHINA for the wet infrastructure and by CFM for the dry infrastructure, superstructure and labor. Since the privatization of CFM in 2001, different parties can obtain a concession to procure these services.

As described in the system analysis, a consistent policy has to be developed, in order to get the system spiral up again. In order to create any return on investment in the port, all possible opportunities should be exploited. This means that in an integrated plan the ministries of Agriculture, Fishery, Industry and trade, Tourism, Environmental issues and Transport and communications should align their policies considering the district of Angoche.

The formal relations between all parties mentioned can be represented as follows on the next page:



Transport of consumer goods, Nampula



Fruit terminal, Maputo

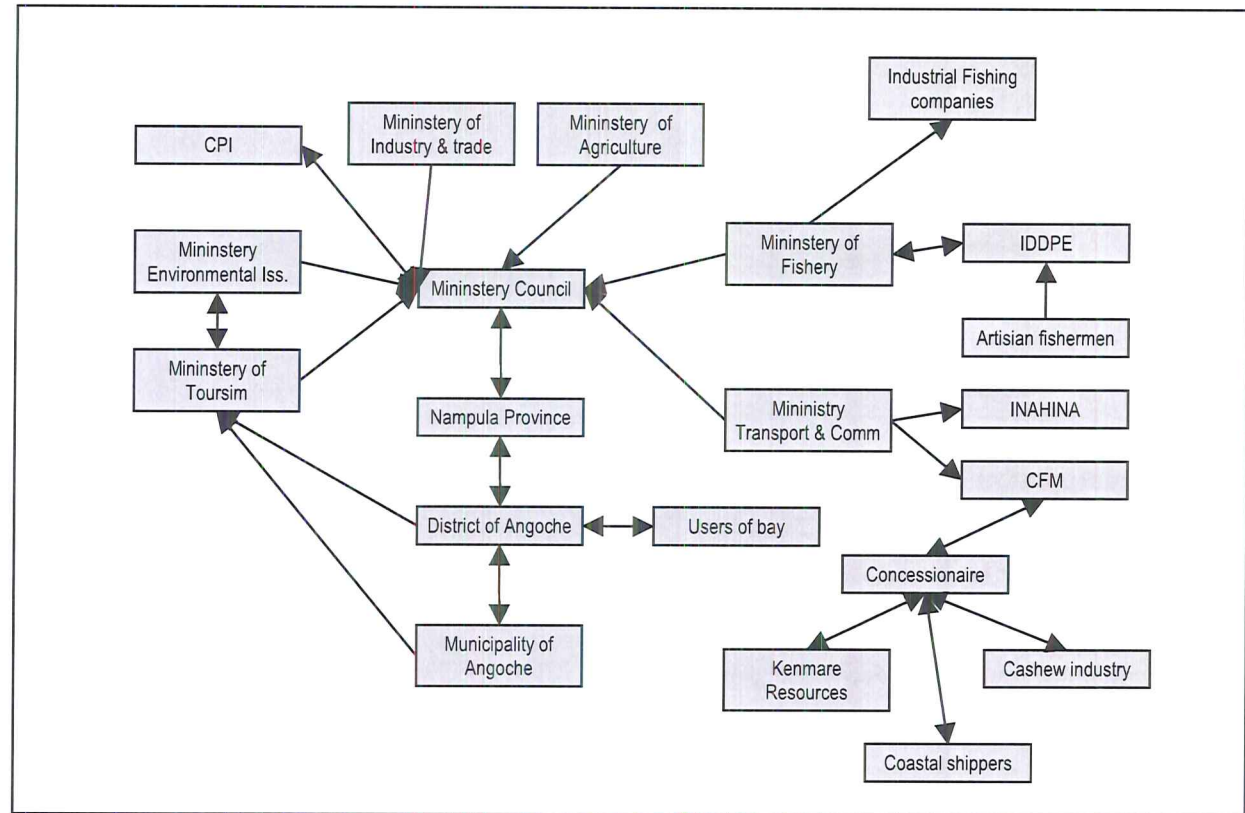




Cathedral, Nampula



Future generation, Buzio Island



### 3.5. Conclusions

The last step in a actor and network analysis is the confrontation of the initial problem formulation with the results of the analyses and describe the consequences. The main conclusion of this analysis will be that there is no straightforward opposition to the development of the port of Angoche. The main problem concerning the field of actors is the motivation and involvement of some critical actors. In the region the focus is on Nacala and Ihla de Moçambique. However the local industries like cashew industry, fishery and commerce have a lot of potential and can be helpful. It may be a good idea to, instead of one large private investor like Kenmare, form a coalition of smaller private parties. It is obvious that waiting for higher-level government to take action is not very fertile and that the district has to take matters into its own hands.

## 4. Possible future developments

System and problem analyses only maintain their value during a limited amount of time due to the always-changing environment. Therefore it is important to place the findings in perspective and take into account possible future developments. In this paragraph the major economic opportunities will be analyzed and three scenario's considering their development will be constructed.

### 4.1. Opportunities for the region

In this section the opportunities for the region, which are earlier defined in the system analysis, are subject of further investigation. Agro-industry production, tourism and heavy sands will be analyzed using a SWOT analysis. This analysis describes the strengths and weaknesses of an object and the opportunities and threats in its environment.

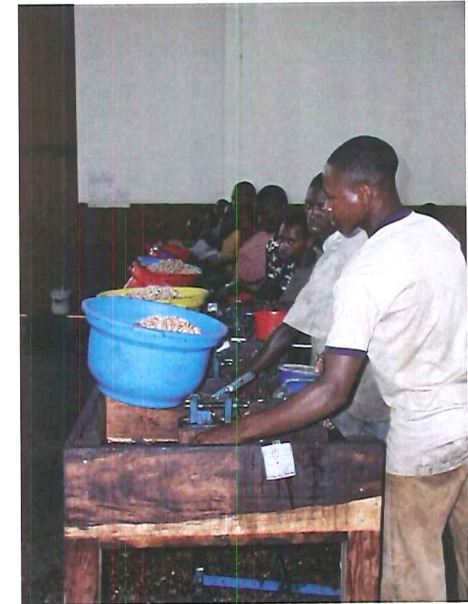
#### Agro-Industry production

Strength	Weaknesses	Opportunities	Threats
Natural resource Labour intensive Low intelligence level Easy to vary or adjust	Dependence on the weather Low value density Possible exhaustion of soil	Fertile environment Available land Presence of ocean Availability of labour	Insects/diseases Extreme weather Lack of infrastructure

The Agro-industry production has always been a driving force behind the economy of Angoche. Making use of the fertile environment and not requiring a high level of education, this sector has a very high potential. However, its performance is highly dependent on weather conditions and even threatened by the extremes. Another major threat is the lack of infrastructure in order to transport the produced goods to an economic market and sell them.

The current production of the Agro-Industry can be found in appendix H. It is clear that the main crop at the moment is the cassava and that is produced for the local market. The District Administration mentions the increase of agricultural production as one of its most important objectives. On provincial level the administration focuses on reducing poverty and improving infrastructure.

When going a little deeper into the Agro-production sector, a couple of more specific aspects were found. The region is historically known for its cashew production. Currently a lot of trees are old and need to be replaced (which is also happening by some aid programs). This crop is also very sensitive for diseases and insects. Sisal production is not very interesting for the international market since plastics have replaced most traditional applications of the product. Cotton is very profitable, however also very



Cashew processing, Miranda Cajú, Angoche



Industrial prawns processing, Pescanorte, Angoche





Timber processing, District of Angoche



Angoche's only tourism facility (2004)

risky since one rain shower can destroy a total harvest. With fishing exists the risk of over fishing, but with the right policy (like the WWF marine park) this risk can be detained. Very good and relatively risk free crops are peanuts, cassava, wheat, coconuts and timber.

### Tourism

Strength	Weaknesses	Opportunities	Threats
High margins Low initial investment Profit stays in region	Very dependent on external factors Seasonal	Natural competitive advantage WWF Marine Park Airport	Current tourism policy Lack of supply industry Lack of infrastructure Language barrier

At this moment tourist facilities are more or less equal to zero in Angoche. However this sector might be very suitable to boost economic activity since initial investment is low and margins are high. It is not that hard to create a pension or a place where people can have a drink. Investment in tourism can be risky because it is extremely dependent on external factors like weather, trends and neighbouring areas. The surroundings of Angoche provide a natural competitive advantage in the tourism industry combining the concepts of 'Bush' and 'Beach'. Also the plans for a WWF Marine park might create a point of attraction. The absence of a decent supply industry and little number of inhabitants that speak English threaten the development of tourism. Again also the lack of infrastructure holds back development since, besides by air, tourists cannot reach the town easily.

Tourism development is a spear point in municipal policy. There are far reaching plans to make Praia Nova and its surroundings suitable for tourists. In provincial policy documents this is no priority, which is mainly due to current national tourism policy. In this policy 17 Priority Area's of Tourism Investment (PATI'S) are mentioned, and for the province of Nampula this is mainly the Ilha de Moçambique region. Angoche is not mentioned in this national policy.

## Heavy Sands

Strength	Weaknesses	Opportunities	Threats
Natural resource High ROI Creates demand for transport & labour	Great impact on environment Profit flows out region Processing industry stays foreign	Increasing demand Situating in middle of concession area	Inaccessibility Radioactivity of soil

A third driving force behind economic development in Angoche could be the exploration of the heavy sands in its vicinity. The ores gained are used to produce titanium. At the moment there is already a concessionaire, Kenmare Resources, who will shortly start exploration. This can generate a large demand for transport and for labour. The value this generates can stimulate the internal market of the region, which in its turn can benefit all. Again the inaccessibility of Angoche is a major threat for pulling Kenmare's logistical headquarters to the town. It might even be more profitable for them to build completely new facilities at site.

## Three scenario's for Angoche

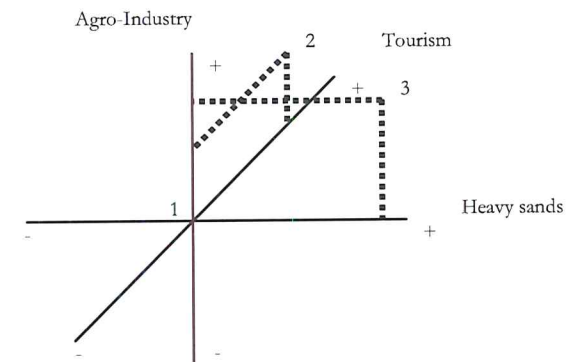
In order to say something about the desirability of the re-development of the port, three scenarios considering the three major opportunities are constructed. The three scenario's can be graphically positioned along the axes of the three opportunities. First a short description will be given, of which a cargo flow is derived.

**1. 'Perished glorious days':** In this scenario Agro-industry production levels will stay at a moderate level to serve the local consumption market and export will not be developed; fishery will be the strongest sector. The ministry council rejects the WWF Marine Park plan and Angoche is no priority area in tourism development. Considering heavy sands, Kenmare Resources will build a new logistical center near Moma because access to Angoche is very difficult.

*Cargo flow:* Small industrial fishing will continue and produce/transport about 10 tons per month. Processed cashew will produce about 30-50 containers a year and some other product groups such as timber, coconuts and cassava can generate some incidental demand for transport. Besides that, local merchants transport about 50 truckloads a month between Nacala and Angoche.



Heavy sand dunes, Sangage



Scenario logic





Tourism development

**2. 'Angoche; hidden treasure':** In this scenario tourism will be the driving force of the economic development in Angoche. The WWF will set up a marine reserve and develop different tourist attractions at Sangage, Praia Nova and some of the islands. Fishery might at first suffer a little from the 'no fishing zone', but will within some years also profit from the renewed supply of fish and prawns. Agro-industry will slowly be able to raise production since they experience positive side effects from the emergence of some supply industry and improvement of the infrastructure. Kenmare will not use Angoche as a logistical node because its insufficient accessibility.

*Cargo flow:* The cargo flow will be the same as in the first scenario, raised with a larger demand for consumer goods. Since agro-industry also experiences positive effects the demand for transport of these products will also rise. The most increase will be found in the demand for transport of people.

**3. 'Gateway to Nacala':** This scenario is based on the fact that Kenmare Resources, which has a concession to exploit the heavy sands North and South of Angoche, will establish its logistical headquarters in the town of Angoche. They will use the port to receive all their supplies directly from Nacala. This strong link with Nacala will attract investors to the region and the increased economic activity will have many positive spin off effects. Mainly Agro-industry will benefit from this link to Nacala and will raise production of export products. Tourism development will never really come of the ground.

*Cargo flow:* The heavy sands operation will need a steady supply of spare parts, energy and food. The more than 400 people that are involved in the operation will generate a large demand for consumer goods. Roughly estimated this will generate a transport demand of about ten containers a month. Since agro-industry finally has a good link with the outside world, it will demand regular shipping of for example cashew, peanuts, coconuts, cassava and wheat. This is estimated at 15 containers a month.



Operational airport of Angoche



Container vessel, Nacala



Angoche, gateway to Nacala?



## 5. Choosing between a road or a port

In the community of Angoche, a lot of people recognize the problem of the lack of infrastructure, however they strongly believe the only solution is the construction of a road to Nampula. Therefore the pros and contras of a port versus a road are discussed here. First they are presented briefly in the table below and will then be further explained.

	Road	Port
<i>Organizational</i>	Dependent on several districts and Provincial government	Is on own territory but dependent on CFM and ministry of Transport
<i>Financing</i>	Private financing almost impossible. Donators can finance construction; maintenance will be a burden on the public budget.	Private financing easier. Donators can finance construction; concessionaire will pay maintenance.
<i>Users</i>	Everybody, both people and industries can use it.	Only industrial users. Perhaps tourists can use it with cruise ships.
<i>Effect</i>	Faster but smaller effect	Long term but larger effect
<i>Environment</i>	Sensitive for raining season Better resistant to cyclones	365 days, 24 hours available Can easier be ruined by cyclone
<i>Reach</i>	Nampula, Nacala	Nacala, Moma, Quelimane, Beira
<i>Employment during construction</i>	High	Lower
<i>Costs</i>	Lower	Higher

A main problem with financing a road is its maintenance. It might be possible to get a donation to construct the road; the maintenance will have to be paid for years and years out of public funds. This leaves two scenario's: there are no more means to finance other basic needs as public health and schooling, or the road will be poorly maintained and quickly deteriorate. Besides, a 200-kilometer road requires much more maintenance than a port, which is concentrated in one area.

However, economic development is not only based on the transportation of goods to the market, it also involves a lot of movement of people. Certainly with Nampula being the administrative capital of the region and harboring an important airport, the interaction between the two places is significant. In the current situation a one-way trip can take between 3,5 to 6 hours in the dry season. During the wet season conditions can be so bad, all types of road transportation might be impossible. A well build road might serve a lot more people than an industrial port. And since the road connection between Nampula and Nacala is in good shape, a road connection with Nampula means for Angoche also a connection to Nacala.

Developing a port can boost some basic economic activities in the region, such as the exploration of the heavy sands and the agro-industry. Also, local merchants can easier import all their consumer goods.



Bridge over Meluli river between Angoche and Moma



Port of Angoche



This increased economic activity generates more employment and the presence of a better supply industry helps setting up tourism facilities. Thus, although the effects of investment in the port might only show after quite some time, the potential is far larger.

In the end the final choice between a road and a port depends on future developments. In a scenario where transport of people becomes most important, the choice for the road is obvious. In the case industry is taking off, an industrial port is more promising.



Public transport by road, Nampula



Cargo road transport, Angoche



Cargo road transport (unused), Angoche



Public transport by sea, Angoche

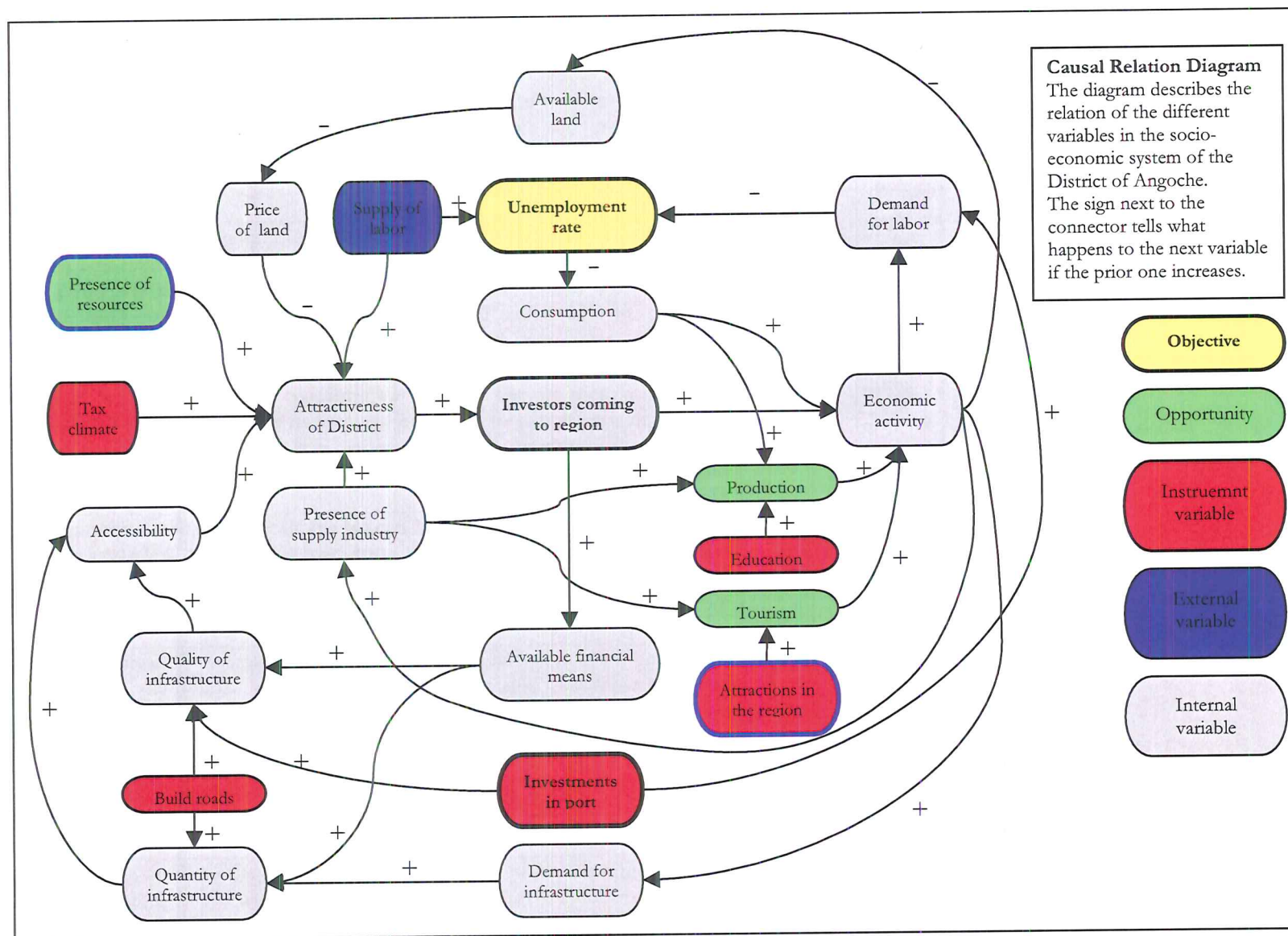


Public transport by air, Nampula



Public transport by rail, Maputo

## Appendix A: economic system in the District Angoche







People of Angoche



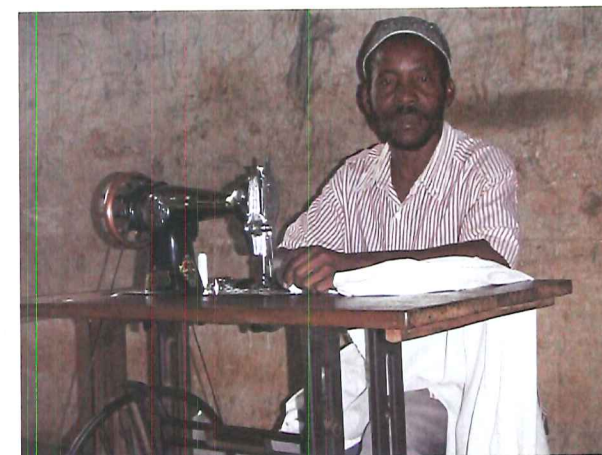
Central market, Angoche

## Appendix B: Variables

Variables	Description
Unemployment rate	The objective variable; it is desirable to influence the system in such a way that this variable goes down. It is calculated by dividing the amount of unemployed workforce through the total supply of labour. The rates for the past years are not exactly known, but dwell somewhere around 75%. The number of 'registered' unemployed has increased with an average of 9% per year in 2003 and 2004 ( <i>Ministerio de Traballo, Angoche</i> ).
<b>Opportunities</b>	
Tourism	It has been proven that third world country communities can very much benefit from tourism since it brings currency, new business opportunities and economic activity to the region. Tourism development is a priority in the policy of the Province of Nampula. The northern coast of Mozambique has a natural competitive advantage. It offers the ultimate tourism product: Bush & Beach ( <i>Ministerio de Turismo, Maputo</i> ).
Production	'Production' as it is used here covers both agricultural as industrial production. The soil in the District of Angoche has proven to be very fertile for all sorts of crops. At this moment cashew, peanuts, sisal, timber and coconuts are most promising on short term. Besides that fishery has always had a very strong potential for export.
Presence of resources	The District of Angoche is rich of natural resources. The most important are the titanium fields along the coast, both north- and southbound. A 25-year concession has been granted to exploit these fields, which can bring positive side effects to the region. Besides that, the area is famous for its fish and timber.
<b>Instruments</b>	
Investments in port	By making the port operational again, a valuable overseas connection with Nacala can be established. This will improve the region's accessibility and enlarge its attractiveness. It will allow all sorts of products to be imported and exported.
Build roads	Creating new, or upgrading and maintaining the existing roads between Nampula, Nacala and Moma will also improve the region's accessibility a lot. The same benefits as an overseas connection can be reached, although in general, transport over water is cheaper than by road and, especially in the rainy season, more reliable.
Tax climate	Tax legislation should be designed in such a way to attract investors to the region as well as to stimulate investments in infrastructure and labour intensive industry.



Education	Training operators, farmers and fishermen will increase efficiency in production, industry and transport.
Attractions in the region	This is both an instrument and external variable. The nature of the District provides many tourist attractions but government still has to utilize these opportunities. The main attractions at the moment are Sangage and Praia Nova. The Province of Nampula has jointly with the Province of Zambezia and the World Wild Foundation developed a plan for a large marine park stretching from Angoche to Pebane.
<i>External</i>	
Supply of labour	In this system description the only 'pure' external variable. Local government has to deal with a large population that needs employment. On the contrary to the situation in the 'Western world', people do not easily move away to find a job elsewhere, due to strong family and social ties. Therefore the supply of labour can in this case be described as more or less a stable factor.
<i>Internal</i>	
Economic activity	Economic activity is best defined by the number of enterprises in the District and the gross-turnover they jointly generate. This factor is mainly influenced by the number of investors coming to the region and the production level of agriculture and industry. Besides that, an increase of consumption in the local economy also generates more activity.
Investors coming to region	Investors do not only bring the essential financial means, but also knowledge, assets and vision to the region. The number of different investors and the total amount of investment they provide can express this variable.
Attractiveness of District	An attractive District with viable business opportunities will bring the investors to the region. This variable is very hard to quantify since it is a mixture of all sorts of factors, both hard and soft.
Accessibility	Accessibility is essential for the development of any economic activity. It is defined by both the quantity and the quality of infrastructure. It is very difficult to judge this factor since every activity demands different infrastructural needs. In general it can be said that every location of economic activity at the very least, needs one easy functional way of access.
Quantity of infrastructure	This issue is especially relevant for third world countries like Mozambique. At most places good accessible roads, ports or railways do not even exist. It can be expressed in kilometers of surfaced roads, number of ports or kilometers of railway line.
Quality of infrastructure	And even where infrastructure exists, it is often in poor shape due to a total lack of maintenance. Investments, for which the financial means are often absent, are hardly needed.



Economic activity, Angoche



Accessibility: road Nampula - Angoche





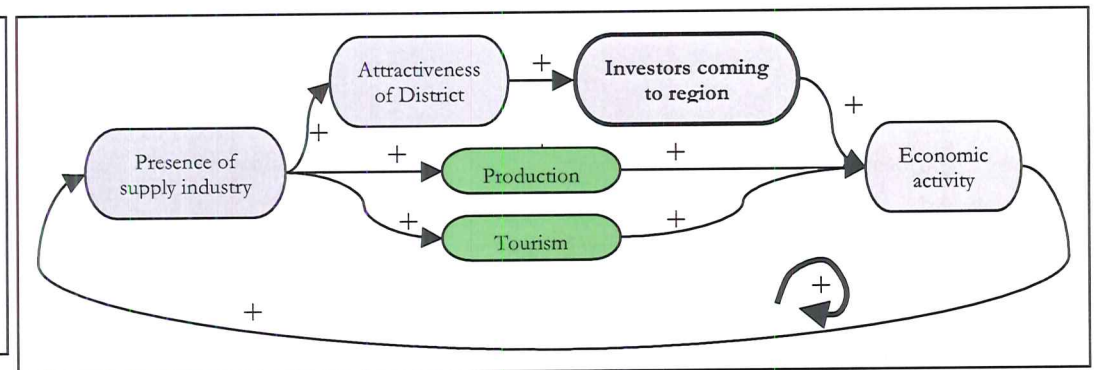
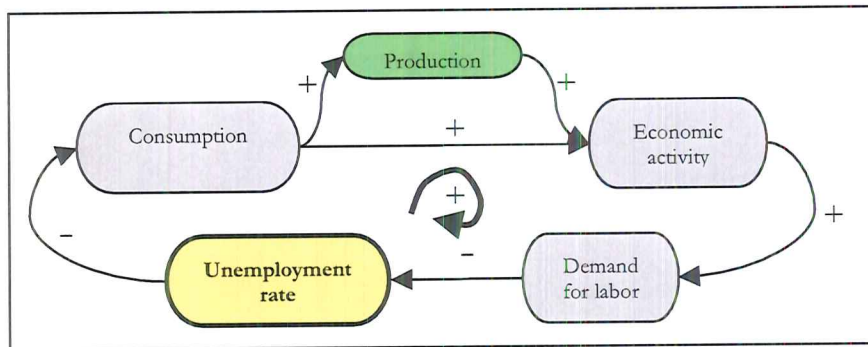
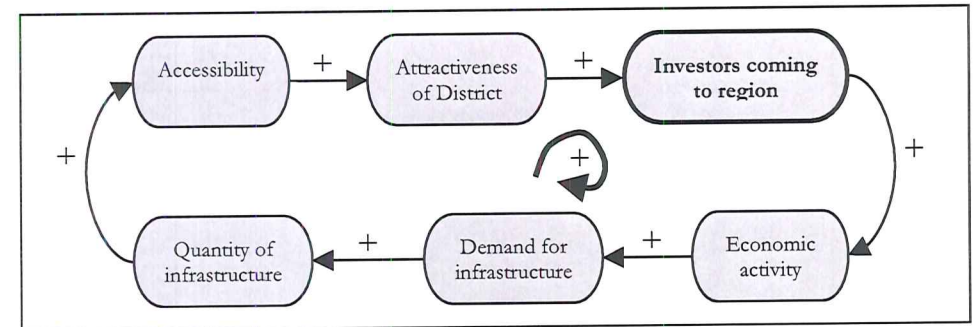
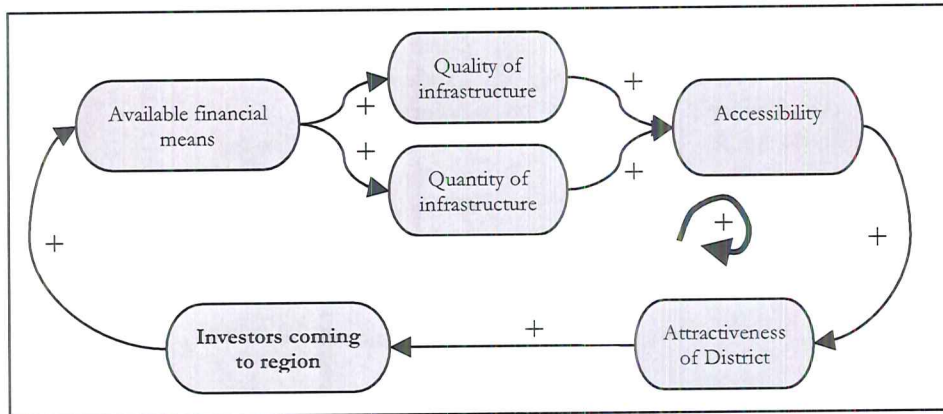
Supply of labor, Angoche



Available land, Sangage

	hardly needed.
Available financial means	To improve existing or create new infrastructure financial means are needed. These can be generated by either private investors, taxes earned with increased economic activity and donators. It can be expressed by the amount available for investment.
Demand for infrastructure	When economic activity in the region increases, more cargo has to be transported so more vehicles use the infrastructure. This will generate the need to either build new or improve existing infrastructure.
Presence of supply industry	In order to develop any agriculture, industry, tourism or exploitation of natural resources at a larger scale, the presence of supply industry is essential. This causes somewhat a 'chicken-and-egg' problem since as long as there is no production or tourism, supply industry will stay away.
Price of land	At the moment land is very cheap in Mozambique, which has a positive effect on the attractiveness of the region. It is obvious this price is influenced by the demand and availability of land.
Available land	This factor is influenced by the increase of economic activity, which occupies land and the land allocation programs that are developed by local government. At the moment the absence of these programs pose a limitation on the development of tourism, since e.g. a hotel does not want to end up next to a waste disposal.
Demand for labor	In order to reduce the 'unemployment rate', this variable needs to rise. This can happen through the increase of economic activity, which creates employment. It can be expressed by the number of jobs present in the region.
Consumption	If more people get a job and poverty is reduced, this will also stimulate local consumption, which has a positive effect on economic activity.

## Appendix C: Positive 'feedback loops'

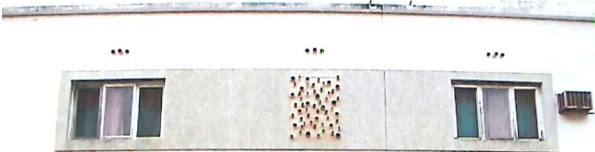




## Appendix D: Ministries of Mozambique



Department of Municipality, Angoche



Directorate of Justice, Angoche

- |  |                                 |
|--|---------------------------------|
| 1. Ministério da Administração Estatal                 | (State administration)          |
| 2. Ministério da Agricultura e Desenvolvimento Rural   | (Agriculture)                   |
| 3. Ministério para os Assuntos dos Antigos Combatentes | (Veterans)                      |
| 4. Ministério para a Coordenação da Acção Ambiental    | (Environmental issues)          |
| 5. Ministério da Cultura                               | (Culture)                       |
| 6. Ministério da Defesa Nacional                       | (Defense)                       |
| 7. Ministério da Educação                              | (Education)                     |
| 8. Ministério do Ensino Superior, Ciência e Tecnologia | (Sciences)                      |
| 9. Ministério da Indústria e Comércio                  | (Industry and Trade)            |
| 10. Ministério do Interior                             | (Domestic affairs)              |
| 11. Ministério da Justiça                              | (Justice)                       |
| 12. Ministério da Juventude e Desportos                | (Youth and sport)               |
| 13. Ministério da Mulher e Coordenação da Acção Social | (Women and Social security)     |
| 14. Ministério dos Negócios Estrangeiros e Cooperação  | (Foreign affairs)               |
| 15. Ministério das Obras Públicas e Habitação          | (Public works and housing)      |
| 16. Ministério das Pescas                              | (Fishery)                       |
| 17. Ministério do Plano e Finanças                     | (Planning and finance)          |
| 18. Ministério dos Recursos Minerais e Energia         | (Mining resources and energy)   |
| 19. Ministério da Saúde                                | (Public Health)                 |
| 20. Ministério do Trabalho                             | (Employment)                    |
| 21. Ministério dos Transportes e Comunicações          | (Transport & Telecommunication) |
| 22. Ministério do Turismo                              | (Tourism)                       |

Source: <http://www.govmoz.gov.mz/ministérios-Moçambique.htm>

## Appendix E: List of actors involved

To improve readability, they are categorized in 'Public parties', 'Non-Governmental organizations', 'Private parties' and 'Non organized parties'.

### Public parties:

- Ministry council
- Ministry of Transport and Communication
- Ministry of Fishery
- Ministry of Environmental Issues
- Ministry of Tourism
- Province administration of Nampula
- District administration of Angoche
- Municipality of Angoche
- Instituto Nacional de Hidrografia e Navegação (INAHINA); is responsible for the wet infrastructure along the coast of Mozambique. They conduct surveys about the water depths, deploy buoys and issue out hydrographic maps. They collect a direct port tax for their services.
- IDPPE: Small scale fishery support Institute
- Centro de Promoção de Investimentos (CPI); designs tax legislation and supports possible foreign investors.

### Non-Governmental Organizations

- World Wide Foundation; wants to establish a large marine park in front of the coast between Angoche and Pebane.
- Donators; like the World bank which finances projects of rehabilitation or USaid, who finances small scale projects and is active in the region.

### Private parties

- Portos e Caminhos de Ferro de Moçambique (CFM); formerly institute under ministry of transport, privatized in 2001, owns all ports and railways in Mozambique; Issues out concessions for operation of the ports.
- Kenmare Resources PLC; has concession to exploit heavy sands in the districts of Angoche and Moma
- Industrial Fishing Companies
  - Pescanorte; owns state-of-the-art fish processing facility in Angoche, which includes a machine for ice production.
  - Mawipi; is still in a 'setup phase' and waiting for a license to fish shrimp
- Cashew processing industry
  - Miranda Cajú, picked up small scale production in march 2004.
  - Mauricia Cajú, will pick up small scale production somewhere in 2004/2005.
- Nacala Corridor Corporation, possible concessionaire
- Coastal Shipping Companies:
  - Navique
  - Mozline

### Non Organized parties

- Inhabitants of possible affected areas
- Artesian Fishing industry



## Appendix F: Inventory of stakes, goals and problem perceptions

	Stake	Goal	Standard	Core of the problem	Causes	Ways of influence
Ministry council	Improve the quality of life, now and in the future, for all Mozambicans	Increased economic activity in any region will raise tax incomes. Private investment is required.	Gross National Product Public investments needed	Mozambique needs drastic improvements in nearly every sector of the public domain.	The past has paralyzed economy. Public means are insufficient, foreign investors have to be attracted.	Final vote on public investment decisions
Ministry of Transport and Communication	Improve and maintain Mozambique's main infrastructures and communications.	In line with the 'corridor strategy', Nacala is the focal point of port development in the region.	Quantity and quality of roads, rail, ports and communication networks.	Mozambique's basic infrastructure is in very poor condition.	Lack of public funds, war and natural disasters.	Policy development, define and issue projects, issuing laws, vote in Council
Ministry of Fishery	Stimulate, facilitate and regulate fishery and linked activities in Mozambique.	Angoche is and should stay a very important region for international fishing companies and fishing grounds should be preserved.	Tons production/year Number of people dependent on fishing industry.	The production level of the fishing industry is not high enough.	Lack of knowledge, resources, infrastructure and basic facilities.	Policy development, define and issue projects, issuing laws, vote in Council
Ministry of Environmental Issues	Implement a balanced and durable land use policy with preservation and protection of the environment.	The archipel between Sangage and Pebane is a very unique area that has to be protected	Free space (ha) Biodiversity Pollution levels	The (nautical) flora and fauna is threatened and should be better protected.	Intensive fishery, erosion and tourism development.	Policy development, define and issue projects, issuing laws, vote in Council
Ministry of Tourism	Develop and position Mozambique as a world-class tourism destination.	Isle of Moçambique is the focal point of tourism development in the region.	# tourists visiting \$ earned in tourism \$ invested in tourism	The opportunities of tourism for the country are not enough developed and exploited.	Lack of public and private investments, land use plans and supply industry.	Policy development, define and issue projects, issuing laws, vote in Council
Province administration of Nampula	Improve the quality of life, now and in the future, for the inhabitants of the province Nampula.	Development of Nacala has priority but developing Angoche as a feeder port is a plan for the longer term.	Gross Regional Product Public investment needed	Lack or dysfunction of many basic public facilities, high unemployment, poor infrastructure.	The past has paralyzed economy. Assigned budget is insufficient, foreign investors have to be attracted.	Policy development, define and issue projects, policy execution, budgeting
District administration of Angoche	Improve the quality of life, now and in the future, for the inhabitants of the district of Angoche.	Improvement of the infrastructure in the district	Unemployment rate Public investment needed	Lack or dysfunction of many basic public facilities, high unemployment, poor infrastructure.	The past has paralyzed economy. Assigned budget is insufficient, foreign investors have to be attracted.	Policy development, define and issue projects, policy execution, budgeting
Municipality of Angoche	Improve the quality of life, now and in the future, for the inhabitants of the municipality of Angoche.	Tourism development will bring new economic activity.	Unemployment rate Public investment needed	Lack or dysfunction of many basic public facilities, high unemployment, poor infrastructure.	The past has paralyzed economy. Assigned budget is insufficient, foreign investors have to be attracted.	Policy development, define and issue projects, policy execution, budgeting
INAHINA	Create, maintain and document Mozambique's wet infrastructure.	Keep the channel of Angoche navigable.	Water depths Changes in measurements.	Mozambique's coastal waters and waterways are continuously changing which hinders shipping.	Extreme weather, seasons, strong currents and erosion.	Issuing maps Deploying buoys
IDPPE	Improve and protect small-scale fishery and fishermen.	Education and facilities for local artisan fishermen	Tons produced by the small-scale sector Number of fishermen	Small-scale fishery is not working as efficient and effective as is possible.	Lack of knowledge, resources, infrastructure and basic facilities.	Education of fishermen Financial support
CPI	Promote foreign investments into the Mozambican economy.	Help investors who are interested into Angoche either for tourism, fishery or industry.	\$ invested in the country # of foreign investors	There are not enough foreign investors in Mozambique.	Complex legislation, corruption, image of the country, poor infrastructure.	Investment law development Information provision

	Stake	Goal	Standard	Core of the problem	Causes	Ways of influence
WWF	Worldwide preservation, protection and rehabilitation of flora and fauna.	The archipel between Sangage and Pebane is a very unique area that has to be protected	Free space (ha) Biodiversity Pollution levels	The habitat of many species in water and on land is threatened.	Intensive fishery, intensive land use (on the coral island, hunt, erosion.	Lobby Financial support Operational execution
Donators	Spend resources in the most effective and durable way.	Support projects that strengthen economic development.	Budgetary deficit, project costs and project's aim	Third world governments have insufficient resources to develop their country.	Economic productivity is low and does not generate enough tax income; a vicious circle.	Financial means Setting requirements
CFM	Maximum profit, continuity	Finding a concessionaire to run the port of Angoche and getting the best deal.	Operational costs Revenues Tons transshipped	Angoche port cannot easily be operated in a profitable manor.	Low cargo flow, no hinterland connections, quay in poor condition	Concession contract Ownership grounds
Kenmare Resources PLC	Maximum profit, continuity	Explore as effective and efficient as possible the heavy sands in the area.	Quantity and quality of infrastructure Presence of supply industry.	All resources, people and products needed to be transported in and out of the region.	There practically no facilities or infrastructure.	Financial means Location of logistical center
Industrial Fishing Companies	Maximum profit, continuity	Explore as effective and efficient as possible the maritime resources in the area.	Meter of quay space Time to market	Though maritime resources are very rich, doing business is very difficult.	Quays are in very poor condition and insufficient, no hinterland connections. Lack of supply industry.	Financial means Choice of port
Cashew processing industry	Maximum profit, continuity	Produce and process as effective and efficient as possible the cashew in the area.	Transportation costs Time to market	Though the region is very rich in cashew, doing business is very difficult.	Lack of proper infrastructure to receive raw kernels and ship out finished products Lack of supply industry.	Financial means Modal choice (truck or ship)
Nacala Corridor Corporation	Maximum profit, continuity	Enlarge the hinterland of the Nacala port.	Accessibility Tons of possible cargo.	The port of Angoche has poor accessibility over land and over water and is in poor condition.	No hinterland connections, 'Barra' keeps ships out, the current quay is almost deteriorated.	Financial means Operational experience and 'know-how'
Coastal Shipping Companies	Maximum profit, continuity	Transport as much cargo as possible.	Accessibility Port Facilities Tons to transport	Servicing the port of Angoche is not interesting.	Poor navigability and depth of the entrance channel, poor facilities and low cargo flow.	Schedule Tariffs
Inhabitants of possible affected areas	Quality of life, work and environment	Maintain free and safe access to the Angoche bay area and seas.	Amount of nuisance.	Measures to improve the navigability of the entrance channel might have an impact on every day life and habits.	Strong currents, erosion, construction activities, hard-structures.	Lobby and protests Violence, to construction workers or construction
Artesian Fishing industry	Safety and ability to catch fish	Maintain free and safe access to the Angoche bay area and seas.	Amount of nuisance.	Measures to improve the navigability of the entrance channel might have an impact on every day work and habits.	Strong currents, erosion, construction activities, hard-structures.	Lobby and protests Violence, to construction workers or construction



## Appendix G: Critical actors & resources

Actor	Important resources	Replaceable	Dependency	Critical Actor
Ministry council	Final vote on public investment decisions	No	High	Yes
Ministry of Transport and Communication	Policy development, define and issue projects, vote in Council	No	High	Yes
Ministry of Fishery	Policy development, define and issue projects, vote in Council	No	High	Yes
Ministry of Environmental Issues	Policy development, define and issue projects, vote in Council	No	High	Yes
Ministry of Tourism	Policy development, define and issue projects, vote in Council	No	High	Yes
Province administration of Nampula	Policy development, define and issue projects, policy execution, budgeting	No	High	Yes
Municipality of Angoche	Policy development, define and issue projects, policy execution, budgeting	No	High	Yes
INAHINA	Issuing maps Deploying buoys	No	Average	Yes
IDPPE	Education of fishermen Financial support	Yes	Average	No
CPI	Investment law development Information	No	High	Yes

	provision			
WWF	Lobby Financial support Operational execution	Yes	Average	Yes
Donators	Financial means Setting requirements	Yes	High	Yes
CFM	Concession contract Ownership grounds	No	High	Yes
Kenmare Resources PLC	Financial means Location of logistical center	No	Average	Yes
Industrial Fishing Companies	Financial means Choice of port	Yes	High	Yes
Cashew processing industry	Financial means Modal choice (truck or ship)	No	High	Yes
Nacala Corridor Corporation	Financial means Operational experience and 'know-how'	Yes	Average	No
Coastal Shipping Companies	Schedule Tariffs	Yes	Average	No
Inhabitants of possible affected areas	Lobby and protests Violence, to construction workers or construction	No	Low	No
Artesian Fishing industry	Lobby and protests Violence, to construction workers or construction	No	Low	No

## Appendix H: Production levels of the Agro-Industry

May 2004

District of Angoche:

Crop	Enterprises (ton)	Family sector (ton)	Total (ton)
Cassava	0	17.894	17.894
Rice	0	1.161	1.161
Feijoes	50	2.157	2.207
Peanuts	18	1.718	1.736
Wheat	166	773	939
Mapira	0	43	43
Gergelim	50	75	125
Girassol	0	11	11
Sweet potatoes	0	84	84
Alhodao	200	11	211
Hortícolas	0	43	43
Sisal hemp	440	0	440
Total:			24.894

Source: Ministerio da Agricultura



Directorate of Agriculture, Angoche



Timber, District of Angoche



Artisan fishermen, Angoche



Processed cashew, Miranda Cajú, Angoche





## Part 3: Natural system





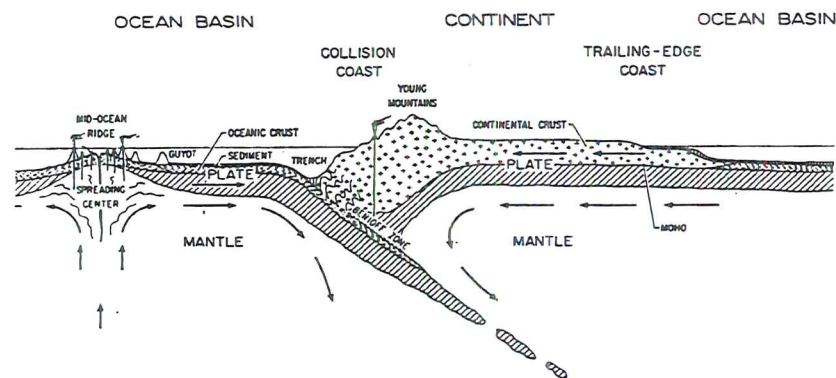
## Natural system

The port of Angoche, as it is the central subject of this report, is geographically encircled by a large estuary. An estuary is a tidal arm of the sea or part of a river that is affected by tides. The way tidal currents and rivers influence the geometry of the tidal inlets, and visa versa, makes the estuary a complicated natural system. This part analyses this complicated system. In the first chapter a brief outline of the geological background of the research field is given. It explains the origin of the shape of the coast.

## 1. Background of the coast of East-Africa

### 1.1. Morphological history

The African continent occupies a position in the middle of a crustal plate that has little tectonic activity along its margins, and has been relatively stable for millions of years. Regarding its plate tectonic setting and the typical coastal features, the East coast of Africa is called an Afro-trailing coast. Erosion processes have converted hills and cliffs into coastal and submarine plains and along these coasts, one can find very large deposits of sediment. The coast is shaped and reshaped by currents, wind and waves. Along Afro-trailing coasts one finds barrier islands, deltas and other sedimentary shapes. The modest-to-large river systems drain areas of only modest relief, so sediment gets a lot of time to be deposited before arriving in the river mouth. Therefore these coasts have developed pronounced continental shelves and coastal plains, but these sedimentary features will not develop into large river deltas. The largest river in Mozambique is the Rio Zambeze. Modest rivers are the Rio Púngoe and Rio Save both in the province Sofala, the Rio Meluli in the Nampula province, the Rio Limpopo in Gaza province and the Rio Messalo in the Cabo Delgado province.

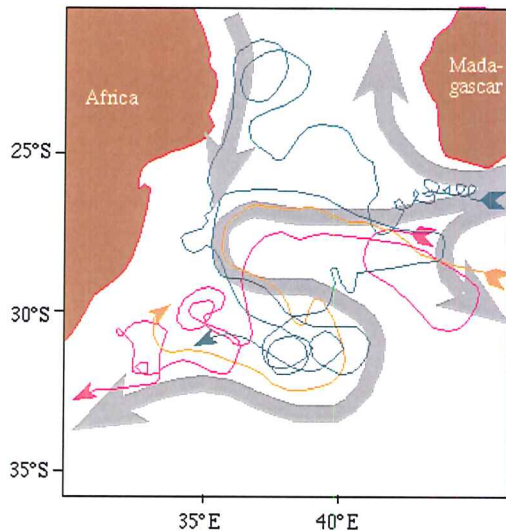
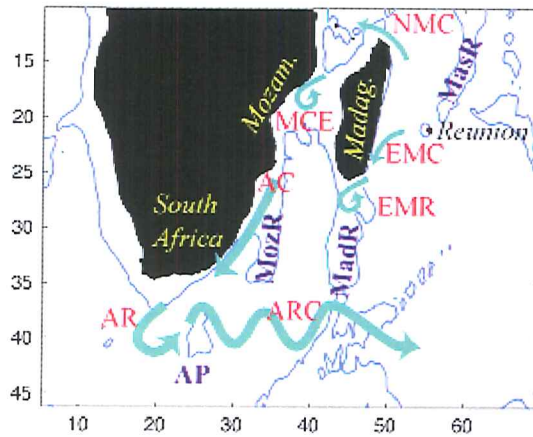


Praia Nova, Angoche



Entrance channel estuary of Angoche





### East Africa Regional Sea: biodiversity data

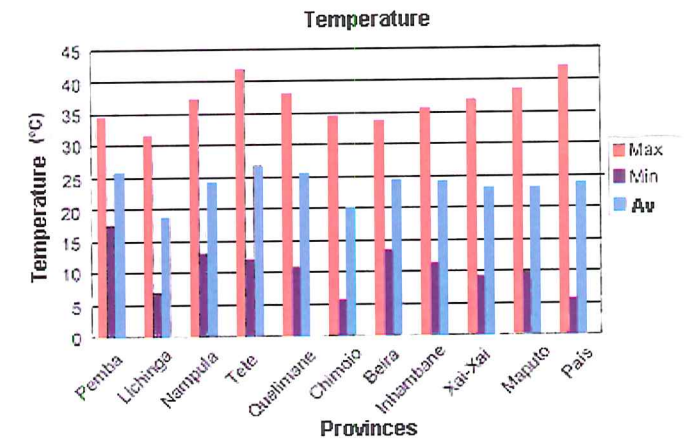
	endemic	T	%		endemic	T	%
sea grasses	0	11	23	sharks	3	73	21
coral genera	0	63	57	seabirds	2	44	15
molluscs	0	80	2	cetaceans	0	27	35
shrimps	0	54	16	sirenians	0	1	25
lobsters	2	37	25	pinnipeds	-	0	-

Table 1.1: Biodiversity Data

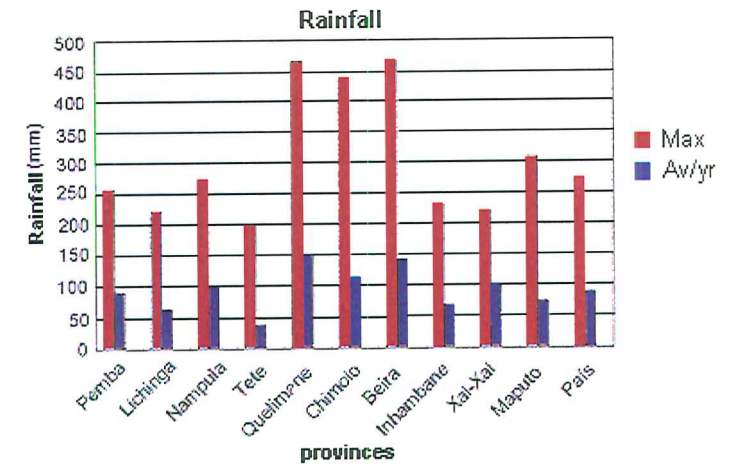


When the Madagascar current reaches the Southern tip of Madagascar, it branches. As mentioned earlier, one branch of the Madagascar current flows down South and joins the Agulhas current. The other branch flows from the southern tip of Madagascar through the Mozambique Channel further to the North: it flows in the opposite direction of the Mozambique Current. This phenomenon is clearly shown in the figure on the left. A satellite observed oil bilging by a tanker. We see that the tanker is travelling from the bottom of the frame toward the top, because the older area of the slick, which has been bilged over a period of about 45 minutes, shows greater dispersal than the more recent section toward the top of the frame.

STS-51I, August-September 1985. Picture #511-42-040

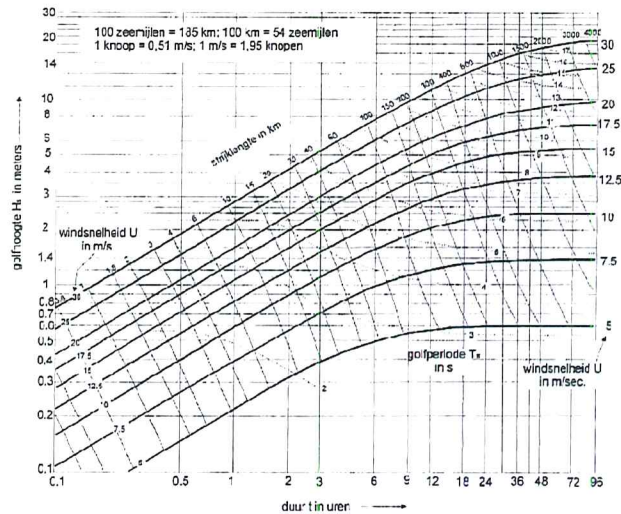


Temperatures of Mozambique



Rainfall in Mozambique





Figuur 3-43: Nomogram geldig voor diep water

Now we will determine the average wave height.

It can be seen from the Nomogram below that, considering the given wind conditions, the mean wave height out of the coast of Angoche is 1.1 m and the wave period is 4 seconds.

For deep water it follows that:

$$c = \frac{gT}{2\pi} \approx 1.56 \cdot T$$

$$c = 1.56 \cdot 4 = 6.24 \text{ m/s}$$

$$L = c \cdot T$$

$$L = (6.24) \cdot 4 = 24.96 \text{ m}$$

$d$  = Average depth

$c$  = Wave velocity

$L$  = Wave length

$T$  = Wave period

For deep water the following applies:

$$\frac{d}{L} \approx \frac{1}{2} \Rightarrow \frac{d}{L} = \frac{1000}{24.96} = 40.1$$

## 1.5. Waves

In a morphological process, the waves are the driving force behind the long shore current. To determine the wave climate, it is important to know some conditions of the environment. One can distinguish three different areas where waves propagate. Which area it concerns depends on the ratio of wave high and water depth. The three areas are: deep water, surf zone and shallow water. Waves are driven by the wind. The wave height depends on the wind conditions. In Angoche we meet the following wind conditions:

- Wind force.

In the surroundings of Angoche the mean wind speed is 7.5 m/s.

- Fetch.

The wind blows over the ocean over a distance that is relatively small compared to the distance between the coast of Mozambique and Madagascar. We assume there is a fetch of 500 km.

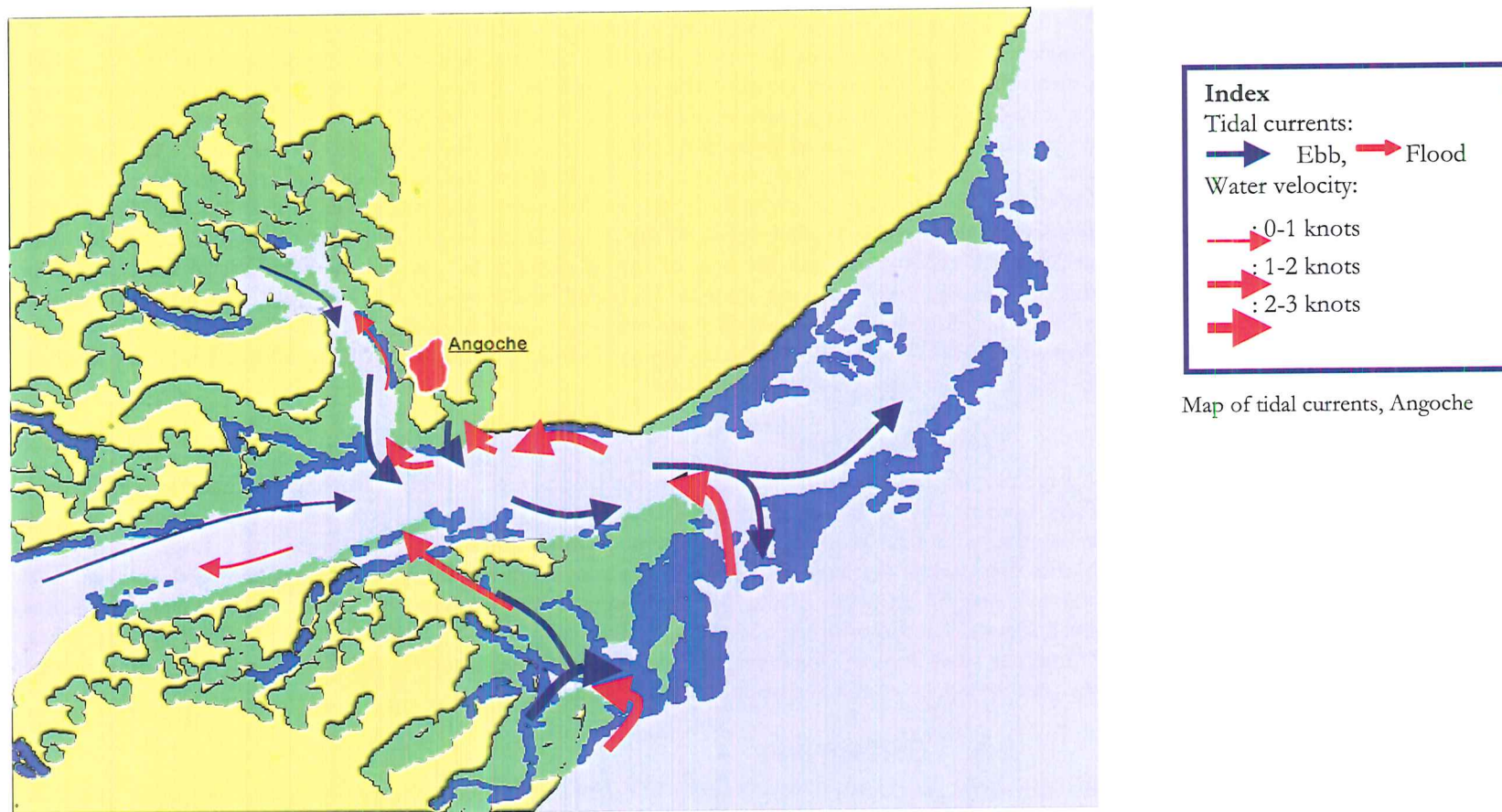
- Duration.

We assume the same wind condition (wind force and fetch) holds for nine hours.

- Water depth.

We assume an average depth over the whole fetch of 1000m.

After a profound field research the distribution of the tidal currents has been charted. See chart below.



Map of tidal currents, Angoche



## 2. Appearance of the estuary of Angoche

### 2.1. The coastal region of Angoche

The coastline in the region of Angoche is a straight, sandy coast. From south of Moma to north of Angoche, 5 to 20 kilometres from the coast, out on sea, one can find several coral reef islands, which protect the coast from wave erosion. The coral reefs are situated on the western boundary of the ocean, on a steep continental slope, which reaches to a depth of 100 to 500 metres. On the landside of the coast, a large number of small rivers drain off in the Indian Ocean, e.g. Rio Moma, Rio Larde, Rio Meluli and north of Angoche the Rio Xitalane, the Rio Sangage, the Rio Mogincual and Rio Mepui. The Rio Meluli and Rio Mepui form respectively the southern and northern border of the Angoche district. The rivers have given access to tidal waves, so the sea could penetrate the district of Angoche. Together with occasional breakthroughs and flooding of coastal plains it has created the geometry of the coastline in this day and age. Small estuaries alternate elongated barrier islands and long spits. The integrated system of channels, flats and islands, which surrounds the city of Angoche, is by far the largest estuary in the Angoche district. It stretches out 30 km along the coast and it reaches 20 km inland. The next paragraph gives a profound description of the estuary.

### 2.2. Geometry

A large part of the estuary of Angoche consists of triangular island, called Ilha de Angoche. The Eastern flank borders on the Indian Ocean, while the Southern and Northern sides both border a 20 to 30 kilometres with tidal channel. The southern channel, the smaller Rio Quilia, runs from southeast to North West, while the large Canal the Quilia runs from the North East to South West: the two tidal channels meet in the Western angle of the triangular. Ilha de Angoche is encircled by a large number of small islands. The largest islands are Ilha do Buzio and Ilha de Quelilene, both inhabited by local tribes. Numerous small streams, for example Canal de Mitubane, Canal de Cotu and Canal de Janga, penetrate the great triangular island. See maps 3,4 and 5 in Part 6.

### 2.3. Surface area

By analysing a geographical map (Source: *FOLHA N° 55-56-64. Direcção dos Serviços Geográficos Cadastrais, rediçãõ*), scale 1:250 000, the total surface area of the estuary is determined 450 km<sup>2</sup>. The total surface area consists of tidal flats, channels and the outer delta; respectively 250 km<sup>2</sup>, 125 km<sup>2</sup> and 75 km<sup>2</sup>. The surface area of the estuary of Angoche can be compared with the surface area of the estuary of the Westerschelde (428 km<sup>2</sup>) in the Netherlands.

The tide propagates through both channels of the estuary. When they meet in the Western tip, one will find a zero residual horizontal current; “wantij”. At this point of the estuary small, shallow channels appear. Escoffier’s theory says, if the maximum entrance channel velocity  $V_m$  is less than the critical



Fishermen at Praia Nova, Angoche



Mangroves, Angoche

maximum velocity  $V_{cr}$  then any sediment deposited in the entrance will remain there. If the channel is too small and the friction too high, it will be closed by natural processes eventually.

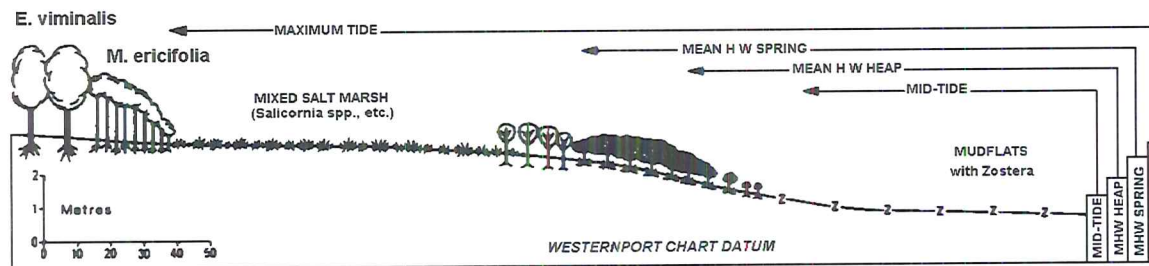
The shipping route from the open sea to the Port of Angoche is situated in the northern inlet. After determination of the “wantij”, it is valid to assume that there is no exchange of water between the northern and southern inlet. The assumption of zero circulation is an important fact when discussing the enlargement of the tidal prism. The Northern and the Southern inlet have a surface area of respectively; channels 90 km<sup>2</sup>/flats 170 km<sup>2</sup>, channels 35 km<sup>2</sup>/flats 80 km<sup>2</sup>.

## 2.4. Vegetation

Northern Mozambique has a tropical climate. The coast of Angoche has a moderate wave climate and the rivers supply the estuary of clean oxygen-rich water. Those features create an excellent environment for the growth of mangrove forests. The type of mangrove forest which is found in the surroundings of Angoche, is called the Black mangrove or *Avicennia germinans*. Typical for the Black mangrove is a short root growing upward from lateral runners extending from the central trunk. The mangrove roots provide a sheltered habitat for a specific organisms, e.g. crabs and prawns. They are adapted to an environment intermediate between land and water. Prawns have given Angoche world fame. Since prawns need a mixture of fresh and salt water for their reproduction, the presence of rivers discharging fresh water in the estuary is very important. While providing an excellent environment for a rare and diverse marine life, the mangrove forests prevent erosion of the coast. (see figure on the right)



Mangrove roots



Schematic representation of mangrove forest

## 3. Characterization of the estuary of Angoche

The tidal environment of Angoche can be defined as an estuary on the basis of its morphological characteristics. It's a semi-enclosed water body, connected to the sea, in which seawater is diluted by freshwater. The environment is tide-dominated.

Within the framework of morphology, the estuary can be divided in two sections: the tidal basin and the outer delta. Unlike the outer delta, the basin is relatively stable. The outer delta of the estuary of Angoche is a complex, dynamic system. Both sections will be discussed successively in the following paragraphs.

The tidal wave in the estuary of Angoche has a length of 315 km:

$$c = \sqrt{g \cdot d} \quad \Rightarrow \quad c = \sqrt{9.81 \cdot 5} = 7.0 \text{ m/s}$$

$$L = c \cdot T \quad \Rightarrow \quad L = (7.0 \cdot 3.6) \cdot 12.5 = 315 \text{ km}$$

$d$  = Average depth over the outer delta

$c$  = Wave velocity

$L$  = Wave length

$T$  = Wave period

A short tidal basin has a length  $\leq \frac{1}{4} \cdot L$

The basin of the estuary of Angoche has a length of 30 km

$$\Rightarrow \frac{1}{4} \cdot 315 = 79 \text{ km} \geq 30 \text{ km}$$



### 3.1. Tidal basin

The tidal basin consists of the two branching channels (Rio de Quilia and Canal de Quilia), ebb- and flood chutes, intertidal sand and mud flats, and mangroves. The basin of the estuary of Angoche has relatively wide flats and shallow channels. Inside the basin the morphological activity is mainly driven by interaction between the bottom and the tidal motion.

#### Long or short tidal basins

There are two types of tidal basins: long and short tidal basins. Which type it concerns depends on:

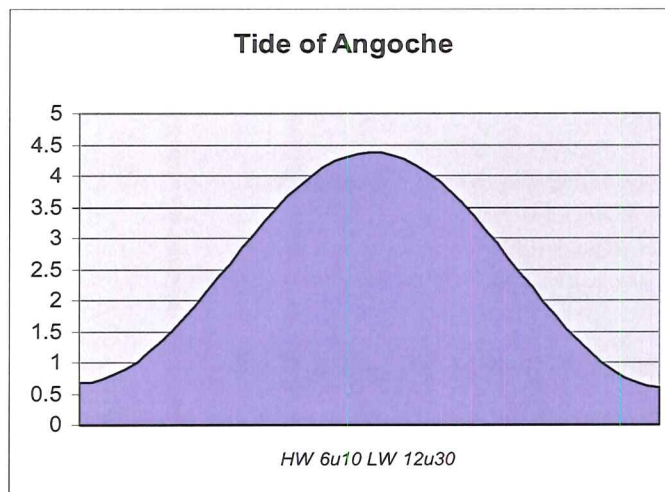
1. The length of the basins compared to the length of the tidal wave  
(see calculations in box on the right)

2. On the type of the tidal asymmetry.

Asymmetry in tides can occur in two different ways. Which asymmetry occurs in a tidal basin accounts for the type of the basin. Furthermore the tidal asymmetry is of great importance for the sedimentation transport in the tidal basin.



Low tide, Angoche



**In short tidal basins** the tidal asymmetry is based on the velocity flux. During the turning of the tide from Low Water to High Water there is more variation in the flow velocity than during turning of the tide from High Water » Low Water. The location of the sedimentation of the fine grain sands is strongly influenced by this difference in the velocity flux. The short tidal basin is mainly shaped by the sedimentation of fine grains. A difference in duration of the turning of the tide causes the velocity flux. If the turning of the tide takes longer, the velocity fluxes are smaller. And if for example the turning of the tide at high tide takes longer than at low tide, most of the sedimentation takes place landinwards. The sediment has time to settle down.

There are other aspects influencing the velocity variations. If for example a tidal basin has large tidal flats, it suggests that there is a lot of sedimentation further inland. Normally in this type of basin, the tide turns quickly. This again suggests a small amount of sedimentation land-inwards. Because of the small depth above the tidal flats, the water velocity drops dramatically. This causes a strong sedimentation on top of these flats. In the estuary of Angoche, the last aspect is stronger than the short duration of the turning of the tide.

**In long tidal basins** the asymmetry is based on duration of tides. Depending on the topography of the tidal basin, the duration of low tide differs from the duration of high tide. If the duration of either high tide or low tide is relatively long the mean flow velocity will be relatively low. For the sedimentation of relatively large particles the duration of the tide is of less importance. The concentration of these larger particles in the seawater is smaller, but a lot of sediment rolls over the bottom of the tidal channels. The flow velocity influences the transport of these larger particles. The difference in duration of tides is often

larger in long tidal basins. This means that also the mean velocity during high and low tide differs, which influences transport of the larger particles. The long tidal basin is mainly shaped by the sedimentation of these larger particles.

To determine whether the tidal basin of the estuary of Angoche is a long or short tidal basin we first take a look at the figure on the left. From this projection of the tide of Angoche it can be seen that there is no significant difference in the duration of high tide compared to low tide. Furthermore the estuary has large tidal flats. There are mangrove forests growing on the flats that slow down the flow so that fine material can be deposited. The tidal basin is shaped by the sedimentation of this fine grains.

These arguments support the conclusion that the estuary of Angoche has a short tidal basin:

Deep channels and width flats characterize the tidal basin. Heavy sediments (gravel and sand) will be deposited in the outer delta, the tidal inlets and the lowest sandy flats. The fine sediments (fine-grain sands) are deposited on the higher flats, where the mangrove forests grow. The finest sediment (clay) sets during slack water, when the flow velocity is minimal. Besides causing sedimentation by slowing down the flow, they also prevent erosion by retaining the soil. This explains the occurrence of steep creeks intersecting the mangroves (see the bottom figure on the right).

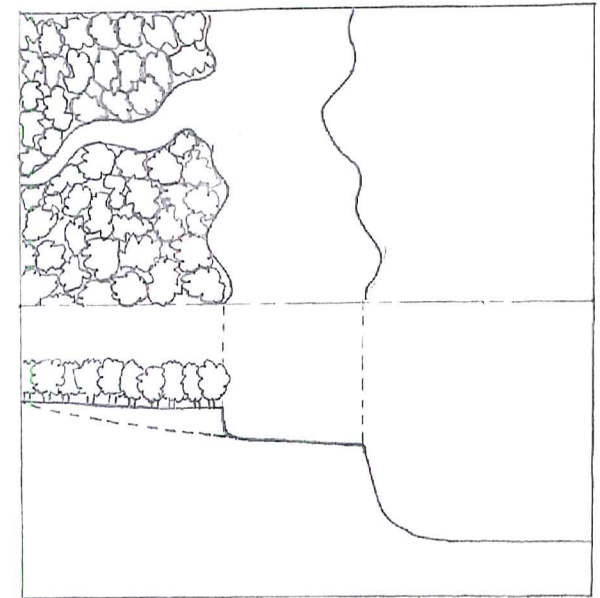
To demonstrate how the asymmetry concerning the velocity flux works for the estuary of Angoche a chronological description of the tidal movement is given.

#### High tide:

- 0 – 1 hour: Turning of the tide out on sea. In the estuary the current velocity, as well as the water level slowly starts to rise.
- 1 – 3 hour: In the outer delta currents are at their maximum. In the deeper (main) channels the water level is rising fast.
- 3 – 5 hour: Due to the increase of the wet cross section the flow velocity in the outer delta slows down. Water enters the creeks in the mangrove flats. The water level in these creeks rises fast.
- 5 – 6 h10 m: Flow velocity in the outer delta further decreases. The tide propagates over the mangrove flats. Due to an extreme increase of basin capacity the water level rises slowly.

#### Low tide:

- 0 – 1 hour: Because the mangrove forest holds the water, the decrease of depth over the flats lacks the fall of the water level lacks the water level on sea. Flow velocity in the estuary is low.
- 1 – 3 hour: Due to gravity flow, the flow velocity increases to a maximum. Water is leaving the creeks in the mangrove flats fast, water level falls fast.
- 3 – 5 hour: The water leaves the flats and is mainly concentrated in the deep channels. The water depth is still decreasing. Also the flow velocity slowly decreases, because gravity flow gets smaller and the bottom friction increases (lower water level).
- 5 – 6 h20 m: There is no gradient in the water level anymore. The bottom friction is still increasing so the flow velocity keeps on decreasing.



Cross section mangrove area



Creeks in the mangroves, Angoche



### 3.2. The outer delta

The outer delta is a dynamic environment. The outer delta is the entrance of the estuary, where the tidal channels meet the open sea. Waves, long shore and cross shore currents all transport energy towards the coast. Part of the energy is dissipated in the outer delta and part of the energy penetrates the channels. An outer delta can be characterised by the way the energy is transported: by waves or by tidal currents. Since both tidal range and wave climate are independent of the inlet configuration of the morphological system, they are very suitable to be used for a hydrodynamic classification. Each hydrodynamic class develops its own morphological features. In the next paragraph we will analyse the type of outer delta we see in Angoche.

#### Tide or wave dominated

The actual classification and topography of the tidal inlet depends on relation between the tidal range and the waves. If a tidal inlet has a large tidal range it will have relatively short barrier islands. A tidal inlet which receives a lot of wave energy is characterized by a relatively small ebb delta. One can distinguish five types of tidal inlets with respect to tide and wave dominance:

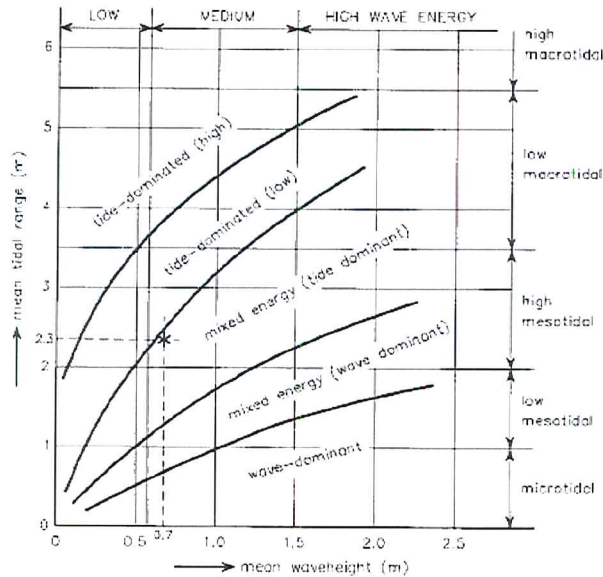
- Wave dominated inlets.
- Mixed energy - wave dominant.
- Mixed energy - tide dominant.
- Tide dominated - low.
- Tide dominated - high.

The tide in the estuary of Angoche has a high mesotidal range (tidal range = 3.02m). With an average wave height of 1.1m it has a medium wave energy climate. According to the Hydrodynamical classification of tidal inlets the estuary of Angoche is tide dominated-low. One of characteristics of a tide dominated inlet (low dominance) is that there are often wave built bars. These bars can be found in the outer delta and form an obstacle for shipping in the tidal inlet.

#### Type of by-passing

In the previous paragraph is already analyzed that the tidal inlet near the port of Angoche is tide dominated (low dominance) and that the type of inlet we find in Angoche shows wave built bars. Besides this wave or tide dominance, the long shore sediment transport also plays an important role in shaping and thus characterizing the outer delta.

The outer delta forms a barrier for this long shore transport of sediment. Sediment may enter the inlet through the flood channel or may be transported from the up drift island to the down drift island either around or over the delta. This process is called sediment by-passing. At the outer delta the littoral transport is interrupted by the outflow of the estuary. The sediment that gets past the inlet proceeds down drift of the outer delta.



\* "Het Friesche Zeegat"



The outer delta of the estuary

There are two types of sediment by-passing:

1. by-passing via offshore bars
2. by-passing by tidal flow action.

Bruun & Gerritsen propose a parameter  $r$  to indicate the type of bypassing:

$$r = \frac{P}{M_{\max}}$$

In which:  $P$  is the tidal prism ( $\text{m}^3$  per tidal cycle)

$M_{\max}$  is the total littoral drift ( $\text{m}^3$  per year).

The stability of the inlet depends on the value of this parameter  $r$ :

- $r < 20$ : inlets become unstable non-permanent overflow channels
- $20 < r < 50$ : the inlets are typical bar-by-passers
- $50 < r < 150$ : the entrance bars are still pronounced (combination of bar-by-passing and flow-by-passing);
- $r > 150$ : the inlets are stable and predominant tidal flow by-passers (little bar and good flushing).

Next we will determine the value of  $r$  for the inlet of Angoche. In the next calculation we assume a net littoral sediment transport of  $250\,000\text{ m}^3$  per year.

#### Type of sediment by-passing

The tidal prism:

The tidal range: 3.02 m

Channel surface:  $220\text{ km}^2$

Tidal flats surface:  $120\text{ km}^2$

Tidal prism:  $220 \times 10^6 \text{ g} 3.02 + 120 \times 10^6 \text{ g} 1.5 = 8.444 \times 10^8 \text{ m}^3$

Bruun & Gerritsen parameter  $r$ :

$$r = \frac{P}{M} = \frac{8.444 \cdot 10^8}{250 \cdot 10^3} = 3377.6$$

As you can see, the inlet of the estuary of Angoche is very stable. This has been varified by observation of citizens and by analysations of hystorical maps.



Praia Nova, Angoche



Fishing boats on wide beach of Angoche





Mangroves surround Angoche



The tide penetrates on all sides of Angoche

## 4. Morphology

A morphological process is a process that influences coastal formation and coastline changes. Morphology can be considered as a sediment balance for a given coastline. The variables of the morphological system are: original topography, water level, wind, waves and currents. The processes driven by the input variables lead to sand transport, which eventually leads to a coastal topography that changes as a function of time. In the following section we will explain what causes transport of sediment and what processes play a role in the morphological system of Angoche.

### 4.1. Sediment transport

The sediment along the coast is transported by a long shore current, i.e. both tidal-driven and wave-driven, and driven by the wind. Now the three types of transport will be described for the coast of Angoche.

#### Sediment transport by the tidal current

In the area of Angoche the continental shelf reaches five miles offshore and is covered by a maximum of 25 meters of water. Further offshore the depth increases to 500 meters. Ten miles out of the coast the sea bottom drops to a depth of 1000 meters or more. The velocity of a long wave is closely related to the water depth; the deeper the water, the higher the wave velocity. In the deep water, ten miles offshore the coast, the tidal wave propagates with high velocity to the north. Since the small depth above the continental shelf allows a lower wave velocity, the tidal wave on the continental shelf cannot keep up with the tidal wave in the deeper part. This natural phenomenon creates a similar effect as a 'spill over'. The coast experiences a rather cross shore current. Therefore the tidal current influences the long shore sedimentation transport only to a small extent.

A good example of alongshore current driven by tide can be found in the North Sea. The continental shelf reaches from the Netherlands to England. This means that almost all of the North Sea is above the continental shelf: the average depth is only 50 meters. Because the continental shelf reaches far offshore the tide propagates in the shallow water of the North Sea. The tidal wave experiences a lot of friction because of this small depth and loses speed on his way. This explains the phase difference between different ports along the Dutch coast and the strong alongshore currents driven by the tide due to a gradient in water depth.

To see how this works for the tide approaching Angoche, the following calculation has been made:

The tidal wave, ten miles offshore the coast of North Mozambique has the following specifications:

The wave velocity:  $c = \sqrt{g \cdot d} \rightarrow c = \sqrt{9.81 \cdot 1000} = 99 \text{ m/s}$



The wave length:  $L = c \cdot T \rightarrow L = (99 \cdot 3.6) \cdot 12.5 = 4455 \text{ km}$

$d$  = Average depth 10 miles offshore

$c$  = wave velocity

$L$  = wave length

$T$  = wave period

These basic equations belong to the long wave theory.

A long wave:  $L \gg d2\pi \rightarrow L = 4455 \gg 1 \cdot 2\pi$

The distance between Moma and Angoche is almost 100 km. The phase velocity of the tide is 99 m/s which corresponds with 360 km/h. From this it follows that if the tidal waves propagates in deeper waters ten miles offshore, it will arrive in Angoche ( $100/360=$ ) 16 minutes later than in Moma. This corresponds with the Tabela de Marés 2004. If it would propagate over the continental shelf it would take longer than 16 minutes.

### Sediment transport by wave-driven current

Obliquely incident waves can generate a long shore current, which transports material. Littoral transport is initiated by hydrodynamic forces. Breaking waves stir up material and create a gradient in shear stress so that the material will be transported. Variations in long shore transport will cause the position of the coastline adjust to the angle of wave incidence. In the next paragraph this will be further outlined.

#### *Radiation stress, wave direction and coastal orientation*

Currents in the littoral zone are caused by hydrodynamic forces, the most important are radiation stress, tidal forces and wind forces. The radiation stress  $S_{xx}$  depends on the water depth, the wave number and the breaker height.

Outside the breaker zone  $S_{xx}$  increases with decreasing depth. An increasing  $S_{xx}$  in landward direction means that a resulting force due to radiation stress is acting on the water column in seaward direction. By a wave set-down equilibrium of forces is achieved. In the breaker zone  $S_{xx}$  is decreasing toward the coastline due to dissipation of energy. This causes a landward resulting force acting on the water column, which results in a wave set-up in landward direction.

The radiation stress is a vector. The directions of the radiation stresses are related to the direction of the wave propagation. If the wave conditions differ from depth a resulting radiation stress occurs which affects the local hydrodynamics.  $S_{yx}$  is the radiation stress in the direction of the coastline that acts on a plane which is parallel to the coast. This  $S_{yx}$  is only present when waves approach the coastline under a certain angle.  $S_{yx}$  also depends on the water depth, wave number and on the wave height. These parameters change inside the breaker zone, so  $S_{yx}$  changes inside the breaker zone. This yields a resultant



Erosion threatens Ilha de Buzio



Wave action





Low tide, Angoche



Lighthouse, Sangage

force in long shore direction, depending on the value of  $dS_{yx}/dy$ . This long shore force is compensated by a force due to bottom shear stress, which affects the sediment transport. Long shore sediment transport depends on the hydrodynamics in the breaker zone and on the sediment properties, so the gradient in the long shore radiation stress  $S_{yx}$  is an important driving force.

Coastline changes only occur where there are spatial gradients in the long shore sediment transport. In areas where wave conditions are influenced by non-uniform bottom topographies, e.g. by constructions like breakwaters the orientation of the coastline will change.

It takes a lot of complex research to define all the variables. In the case of Angoche a plausible assumption will be sufficient. In paragraph 3.2 we assumed a yearly net littoral transport of 250 000 m<sup>3</sup>.

From looking at a chart, the influence of waves on the orientation of the coastline can be analyzed. Close to Angoche there are seven islands in front of the coast, protecting the coast from wave erosion. Further South, close to Moma, there is a curve in the coastline, which shows that wave erosion has taken place. The curve in the coastline and a couple of spits along the coast, clearly show that the wave-driven current is directed up North. This corresponds with the fact that during the rainy season the mainly wind direction is South. During this season the severest weather conditions take place. The wave-driven current plays an important role in the long shore sediment transport.

### The wind driven transport

The wind driven transport is a dry transport along the coast. The sand is carried by the wind over the beach. Most sand is transported during the dry season. In this season the wind is predominantly directed Northwards, which causes a northward direction of the wind driven sand transport..

wind force (Beaufort)	wind speed (m/s) (approx.)	sediment transport (10 <sup>-6</sup> .m <sup>3</sup> /s/m)
3	4.5	-
4	7.0	1
5	10.0	3
6	12.5	14
7	15.5	31
8	19.5	86
9	22.5	165
10	26.5	310
11	31.0	408

## 5. O Porto de Angoche; problems, interventions and solutions

### 5.1. Introduction

The port of Angoche is situated along the Northern channel of the estuary, 10 km inland. In the '70's the port of Angoche, in that time still called Antonio Enés, was visited by more than 270 ships a year. Large amounts of cashew, sisal, cotton, coconuts, peanuts and prawns were exported to all over the world, while all sorts of luxury goods were imported from Europe and Asia. Also in that time ships could only enter during high tide. After entering through the outer delta the ships moored in deeper parts of the channel, in front of the Capitania, where they were (un-)loaded by small barges. The independence achieved in 1974, followed by 20 years of civil strife, chased away the traders and their commerce. Nowadays the only port activity is carried out by small fishing boats.

Before any field research was carried out, the problem for ships visiting the port of Angoche was defined by local government of the Nampula province –initiator of the project- as silting up of the estuary and particularly of the port itself. After analysis of the natural environment and of the history of the port of Angoche it can be asserted that, concerning the morphology, the entrance channels and the port have been in morphologically stable for more then 50 years. The problem concerning navigability is concentrated in the outer delta. Yet, this problem existed in Angoche's Golden Age just the same.

### 5.2. Problem analysis

There are two main routes leading to the port (see route map). On both routes the presence of shoals in the outer delta and the strong tidal current have always made it difficult for ships to enter the estuary. The approach channel, Canal de Quilia, with a depth of 10 to 20 meters, had never had any problem concerning navigability. With the downfall of Antonio Enés, the sailors encountered a new difficulty: many shipwrecks, located in the approach channel and in the entrance of route I, hamper the navigability. On route II the so called 'Barra', a sandbar situated at the entrance, only allows vessels with a draught of no more than 2 meters.

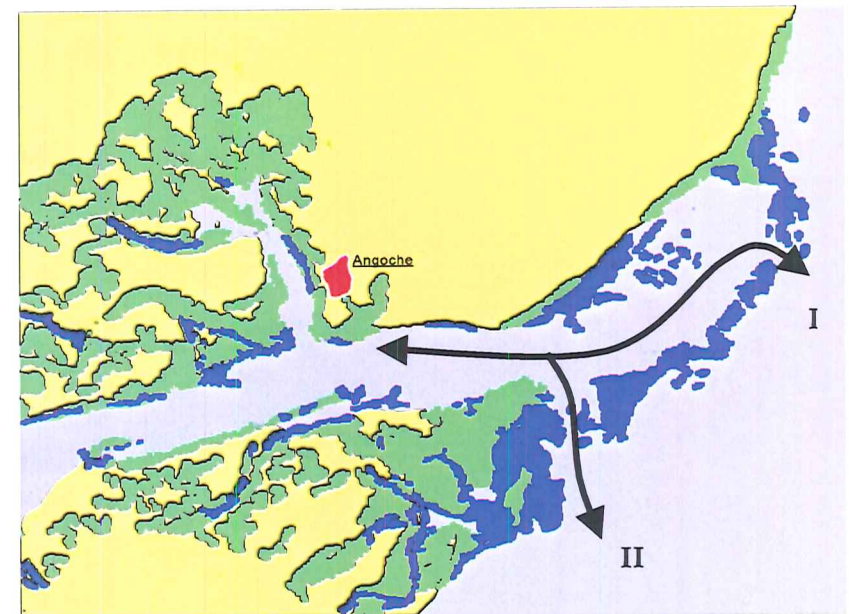
If we summarize the causes of inaccessibility of the entrance of the tidal channel we get:

- Sediment drift along the coast plays an important role in the formation and bypassing of the shoals in the outer delta. These shoals make it difficult for ships to enter the tidal channel, which forms the path to the port of Angoche.
- Seasonal river discharge: During the wet season (November till March) the rivers drain off large amounts of debris in the estuary.
- Extreme weather conditions: Once in a decade a typhoon or cyclone passes Angoche, causes erosion of the coast and changes the geometry of the outer delta.
- Accessibility / navigability in the entrance is hampered by strong tidal currents
- Ship wrecks form a difficult obstruction on the path to the port. Ships were sunk down because they were outdated or during fatal accidents.

#### Index

**I:** Old Portuguese channel

**II:** Fishermen channel



Route map





Facing the 'Barra'?



'Design ship', Navique

### 5.3. Problem definition

The navigability of the entrance of channel, which leads to Porto de Angoche, is obstructed. The presence of ship wracks, shoals, sandbars and strong tidal currents make it difficult for ships, entering the Canal de Quilia, to maneuver in the outer delta.

### 5.4. Main goal

To make the entrance of the channel, which lead to Porto de Angoche, navigable for a certain Design ship.

## 6. Solutions

In the following paragraphs we will try to solve the problem of the port of Angoche. We will focus on how to solve the problem of the presence of shoals and strong tidal currents in the outer delta. Of course, if one wants to solve the whole problem and to ensure good navigability of the entrance channel, besides taking away the problem of the shoals and the strong currents, one also has to remove the ship wracks. But this is out of the scope of hydraulic engineering. To come to a possible solution we will first discuss how one can interfere in the present morphological system and what the consequences will be. Using the MCA the best intervention will be chosen. At the end of this chapter we will combine different intervention to approach the optimal solution and reach the main goal.

### 6.1. Possible interventions

In coastal engineering there are several interventions in the morphological system which can (re-)move shoals and can create protection against strong tidal currents. These possible interferences are:

- Guiding of the ebb stream
- Diverting the present sediment transport route
- Decrease of sediment in suspension
- Enlargement of the tidal prism.
- Dredging

Next each of these interventions will be discussed.

#### Guiding of the ebb stream

In theory the minimum equilibrium cross sectional area of the entrance is linearly related to the volume of the tidal prism. Changing the width of the outflow by guiding the ebb stream through a narrowed exit will disturb the equilibrium. Due to the narrowed exit the velocity will increase and will become higher then the critical velocity. The bottom of the exit will be scraped by the flow and the equilibrium will be restored. After the equilibrium is restored, the flow velocity will be critical again.

Another positive effect is that the water jet of the ebb stream will increase. This will divert the long shore current towards the open sea. Less sediment will join the by passing system.

### Diverting the present sediment transport route

To solve the problem of the presence of shoals and sandbars on the shipping route one could divert the sediment transport route further towards open sea. One way to do this is the construction of a groyne or a dam. The scarcity of construction material, the lack of skilled construction workers and the risk of negative side effects all have a negative effect on feasibility.

### Decrease of sediment in suspension

As said before one way to change the lay out of the outer delta is to intervene in the long shore sediment transport. Sediment traveling along is interrupted by the tidal inlet. While passing the tidal inlet it becomes part of a sediment by-passing system. This sediment can change the lay out of the outer delta and can build up shoals and sand bars, which can cause problems for shipping. By decreasing the sediment in suspension South of the tidal inlet, less sediment will join the by-passing system. This can solve the problems for shipping if sand bars and shoals diminish. A way to achieve this is to construct of a jetty, groyne and/or a sub-merged water wall. The local decrease of sediment in suspension will cause a gradient in the long shore sediment transport, which can cause the possible side effect of lee-side erosion.

### Enlargement of the tidal prism

One can enlarge the tidal prism by changing the surface area. When one changes the tidal prism, one changes the volume of water that enters and leaves through the tidal channel. The tidal basin and the tidal channel will have to store this extra water. The basin can store the water widthways, spread over the enlarged surface area, on top of its flats. The width of the channel stays unchanged: the extra water in the channel water can be stored by deepening the channel due to erosion.

After Escoffier investigated the equilibrium condition of an estuary, it was found by O'Brien that the minimum equilibrium cross sectional area of the entrance is linearly related to the volume of the tidal prism:

$$A = 7.0 \times 10^{-5} * P$$

$A$  = the minimum equilibrium cross section of the entrance channel (throat) measured below mean sea level in  $m^2$

$P$  = the tidal prism volume in  $m^3$

$7.0 \times 10^{-5}$  = a constant reasonable that is calibrated on tidal inlets in the North Pacific, USA. This is also a reasonable assumption for the estuary of Angoche.



Ilha de Buzio and Ilha de Quelilene



Enlargement of the tidal prism?





New land in mangroves, Angoche



Tidal flats, Angoche

By using this theory one can estimate the impact of the enlargement of the tidal prism. In the situation found in the estuary of Angoche two possible ways for enlarging the tidal prism can be distinguished:

#### 1. **Making water out of land.**

By digging away land one can enlarge the surface area of the basin and can create extra storage.

Calculation of enlargement tidal prism by digging away land:

To estimate how much  $\text{m}^3$  of sand has to be removed in the surrounding of the estuary so that the entrance channel will be deepened, we will use O'Briens theory mentioned above. In equation form:

$$A = 7.0 \times 10^{-5} * P$$

At present the southern entrance, route II, has a depth of 2.5 m. In this example we assume that the entrance channel has to be deepened by 1m. The entrance of the estuary has a width of 10 km. If the channel is deepened by 1 m the surface of the cross section is enlarged by at least 10% bigger. This means that  $8.444 \times 10^7 \text{ m}^3$  of sand has to be removed. If a part of land would be changed into a tidal flat, with the same average height above low water as defined earlier, the part of land would have a surface of  $8.456 \times 10^7 / 1.51 = 56 \text{ km}^2$ . This would cause a significant loss of the District of Angoche.

#### 2. **Closing the Southern inlet of the estuary.**

Construction of a barrier in the Southern channel separates this channel from the sea. However scarcity of construction material and the risk of negative side effects do not encourage this intervention.

### **Dredging**

Dredging is way to deepen of the channel artificially. The dredging process can be split up in four sub-processes, i.e. digging (breaking up the cohesion of the soil), vertical transport, horizontal transport and deposition. Dredging equipment is often classified according to its mobility (stationary vs. non-stationary) and according to one aspect of the dredging process (i.e. suction dredge). Possible dredging equipments: trailing suction hopper dredges, cutter suction dredges stationary plain suction dredge or dredging by creating a density current. Required capacity, restrictions to sizes and costs will determine which equipment to use.

## 6.2. Multi Criteria Analyses (MCA)

A Multi Criteria Analyses is a way to analyze different possibilities. Furthermore the Multi Criteria Analyses helps you in choosing the best option. In the next paragraph a Multi Criteria Analyses will be carried out for the possible interventions in the morphological system of the estuary of Angoche.

All possibly interventions are analyzed on the basis of the following criteria:

1. Durability
2. Immediate result
3. Accuracy
4. Probability of negative side effects
5. Physical impact
6. Availability of construction material

Why are these six criteria so relevant? Politics in Mozambique can be sluggish and complicated. For this aspect it is important that the result of a technical operation is transparent and immediate. Among the people who make the decisions in Mozambique and especially in the district of Angoche it lacks of knowledge of hydraulic engineering. For example, if you would choose for the *Enlargement of the tidal prism* and you would propose to dig away large pieces of hinterland, the local government might not understand what this has to do with the shallowness of the entrance of the port and it is likely that they would disapprove of this intervention. So accuracy and immediate result are important criteria.

Also durability is very important: In a poor country like Mozambique a large investment can be done once but not over and over again. Dredging, for example, is an expensive activity, which has to be repeated once in 5 to 10 years. This is impossible for a poor district like Angoche, unless there are private concessions. Another aspect that follows from the financial situation in the region is that availability of construction material is limited. This scarcity has to be taken into account when analyzing the different interventions.

Furthermore Angoche has a vulnerable natural environment with a complex ecological system. Within the estuary seawater mixes with fresh river water. This enables the growth of mangrove forest, that forms a protected habitat for all kind of fish. Because most people in Angoche earn their money in the fishing industry it is important that the ecological system stays unchanged. Therefore the risk for negative side effects and the size of physical impact has to be minimized.

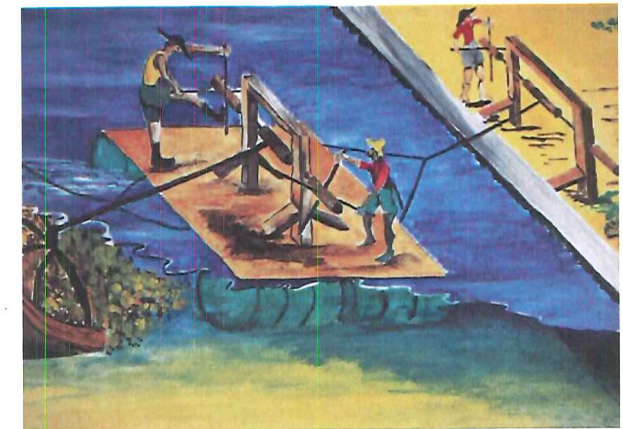
### Explanation MCA

From table 6.1 it can be seen that 'guiding of the ebb stream' comes in first place. 'Decrease of sediment in suspension', 'diverting of the sediment transport route' en 'dredging' are respectively the second, third and fourth best actions. Next we will explain the scores of the different interventions:

1. Guiding of the ebb stream is accurate. The location of the intended effect can be predicted precisely. If one places a dam on a certain spot one knows where the shipping route will be



Dredging vessel



Dredging, traditional method





Dredging, even more traditional method

- situated. Furthermore it is a durable action. By convergence of the ebb stream the geometry of the inlet changes permanently.
2. Diverting of the sediment transport route is a durable intervention. A disadvantage of this intervention is the relative high probability of negative side effects. This is because the dam is not connected to the mainland: there are many mangroves and flats between the surf zone and the coastline. When one places a dam on these flats, reaching into the sea, there is a possibility that the flow will go around the dam, along the back, and will cause a loss of flats or will force back the coastline.
  3. Decrease of sediment in suspension has relatively small impact on the physical environment. The dam will be placed just out of the coast. There will be no loss of land and there will be no people that have to give way to a certain construction. Furthermore just a simple construction will be sufficient. There will be no problem with the availability of construction material.
  4. Enlargement of tidal prism has an enormous impact on the environment. As the calculation in paragraph 3.2 illustrated the action 'making water out of land' will cause a great loss of the hinterland of Angoche. Furthermore it is a very inaccurate intervention. By enlargement of the tidal prism is really hard to aim at one or both of the shipping routes. More likely the outer delta will change over its total width
  5. Dredging is a very accurate action with immediate result. However by dredging away redundant soil in the outer delta, the equilibrium of the morphological system will be disturbed. This disturbance yields equilibrium restoring forces. The removed soil will be refilled by soil out of another area of the estuary. The consequences are that dredging has to be repeated once in 5 to 10 years and that there will be a possible loss of other, vulnerable, parts of land in the estuary.

	1. Durability	MP 5	2. Immediate result	MP 1	3. Accuracy	MP 2	4. Probability of negative side effects	MP 4	5. Fysical impact on the enviroment	MP 3	6. Availability construction material	MP 2	Total score	Multiplied total score
1. Guiding of the ebstream	5	25	2	2	4	8	3	12	3	9	2	4	19	66
2. Diverting of the sediment transport route	4	20	3	3	3	6	2	8	3	9	1	2	16	48
3. Decrease of sediment in suspension	4	20	2	2	2	4	4	16	4	12	5	10	21	64
4.1 Enlargement of tidal prism: Making water out of land	5	25	1	1	1	2	2	8	1	3	2	4	12	43
4.2 Enlargement of tidal prism: Closing the southern inlet	5	25	1	1	1	2	1	4	2	6	2	4	12	42
5. Dreging	1	5	5	5	5	10	3	12	5	15	2	4	21	51

Table 6.1: Multi Criteria Analysis



The weighted scores show which interventions are relatively the most effective. Possibly the most effective solution lies in a combination of these interventions. In the next paragraph possible solutions will be discussed. Combinations of the different interventions are considered. Because the score of the both variations of enlargement of tidal prism is significantly lower than the scores of the other interventions, they will not be included in this consideration.

### 6.3. Possible solutions

In the previous chapter the possible interventions have been discussed. As a result of these interventions, solutions have been developed to improve the entry of the port. In the entrance of the estuary two routes can be distinguished, these are (see figure on the right)

- Route I, the old entrance channel of the port, used by the Portuguese.
- Route II, the present entrance channel of the fishermen.

In the alternatives, both the possible interventions as the two main routes have been taken into account. One can distinguish five alternative solutions.

#### Alternative 1, variant 1

##### *Guiding of the ebb stream – route II*

The first alternative consists of one intervention, a dam near Praia Nova in order to guide the ebb stream. The dam is constructed out of concrete and rocks.

This solution is solely possible in combination with route II, as for route I a dam of enormous dimensions would be required.

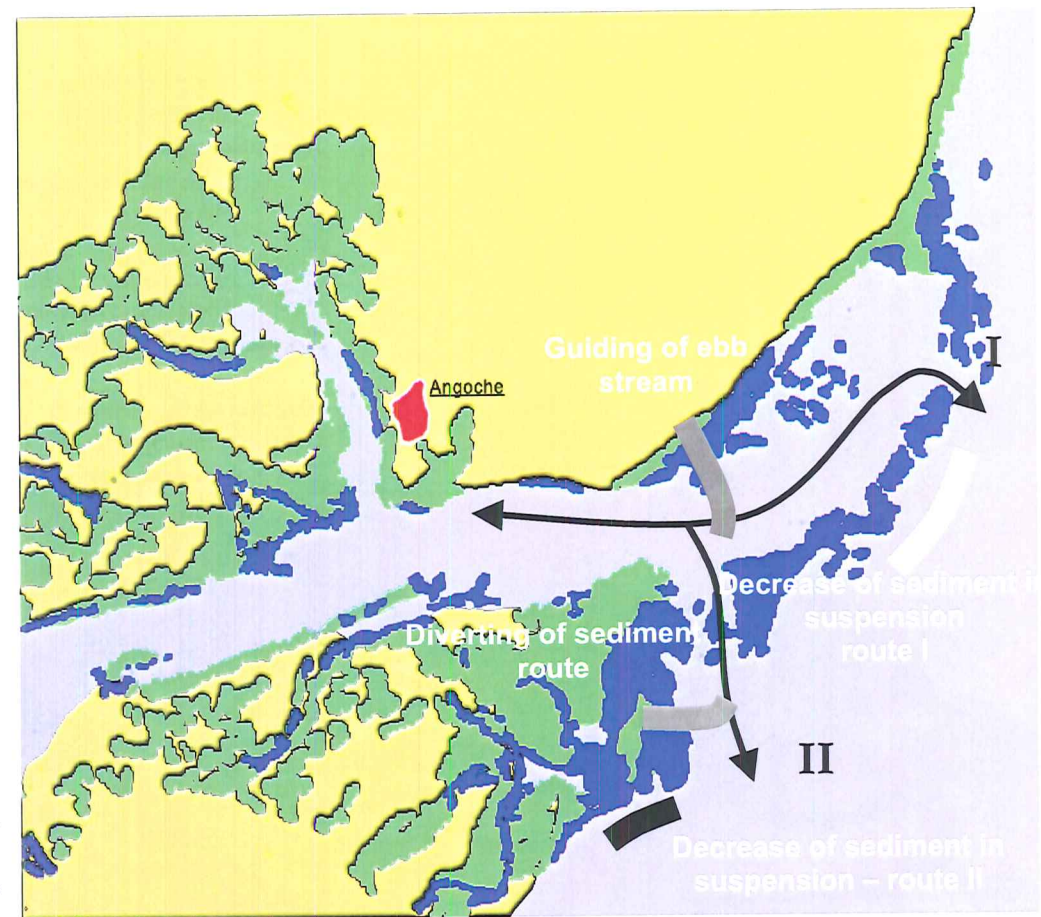
To appoint a suitable location for the dam, two aspects are important:

- The dam should be curved, in order to guide the ebb stream natural.
- The dam cannot be situated in too deep waters; restrictions are put on its dimensions.

The location of the dam is given in both figures (previous and this page).

Advantages:

- Possible growth of mangrove forest at Praia nova, which will protect the coast from erosion. Protection of Praia Nova is one of the policies of the district plan.
- Ilha do Buzio will be located in the inner bend of the guided ebb stream: erosion of the island is prevented and very likely even



Possible solutions

Guiding of the ebb stream





suppletion due to sedimentation in the inner bend will occur, which is good. Protection of Ilha do Buzio is also one of the policies of the district plan.

**Disadvantages:**

- The submerged water wall will be subjected to erosion: a heavy construction of the dam will be necessary.
- Due to the dam the velocity of the outflow will increase, resulting in a decrease of the navigability of the channel. To minimize this negative side effect, the dam is submerged during high tide. But still, strong currents in the vicinity of the dam could occur during high tide.

An example of a suitable construction of the dam can be seen on the right.

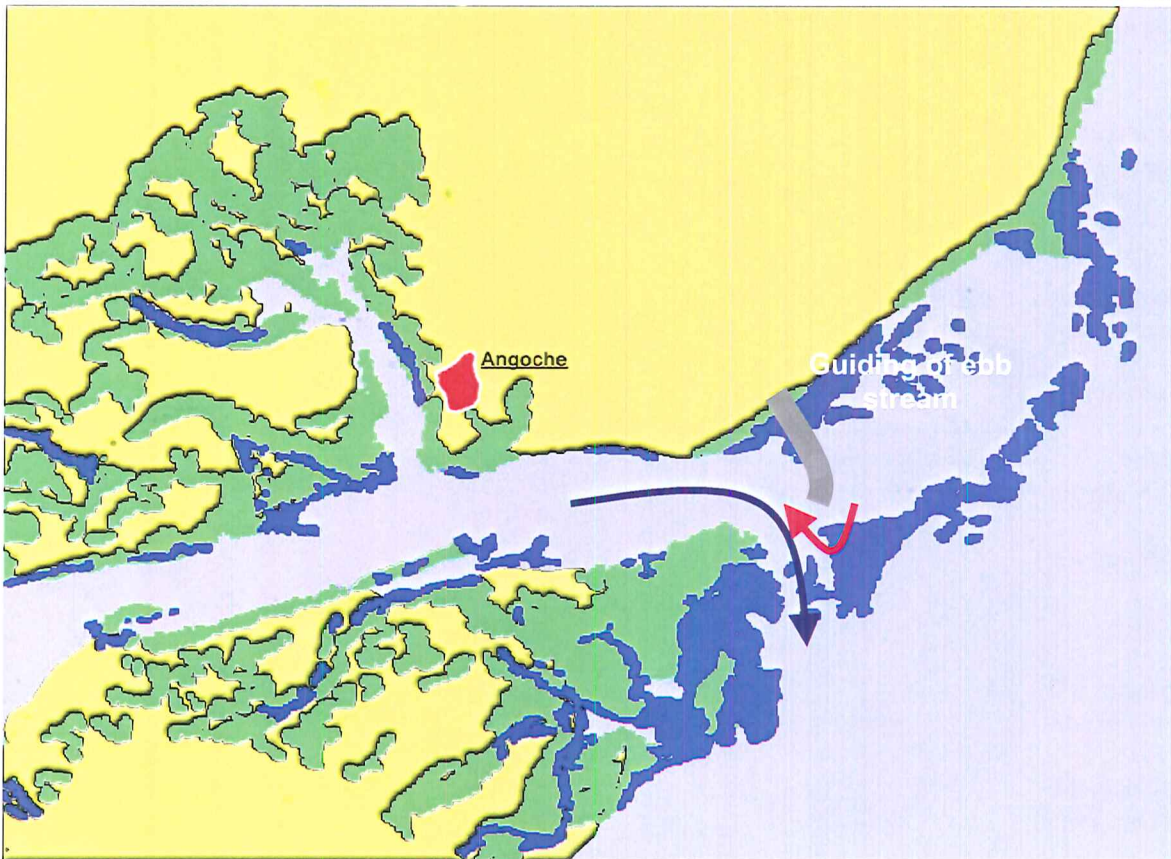
**Alternative 1, variant 2:**

*Guiding of the ebb stream in combination with a decrease of sediment in suspension – route II*

This solution is almost identical to the previous variant but reinforced with an extra intervention: a submerged water wall. This wall decreases the sediment in suspension that passes the entrance of the channel. Due to the fact that the average long shore current is directed towards the north, the wall must be positioned just south of the entrance channel, south-east of Ilha do Buzio (See figure on page 79). The submerged water wall is placed parallel to the coast, over a length of 500 to 1000 meters. The wall can be constructed simply by dumping rocks on the sea bed.

An example of a submerged water wall at low tide is given in see the picture on the next page. The advantages of variant 1 are still active, but the additional wall produces two extra positive effects. These are:

- Extra protection of the islands, such as Ihla do Buzio.
- The relative simple construction can be constructed with local materials.



### Alternative 1, variant 3:

*Guiding of the ebb stream in combination with diverting the sediment transport route - route II:*

The alternative resembles with the first one, but has an extra dam that diverts the sediment transport route further away from the coast. The location of the dam is south-east of Ilha do Buzio (See figure on page 79) and guides the long shore current towards the sea. The dam is constructed out of concrete and rocks. The advantages also apply for this solution, but the dam causes some extra effects.

Advantage:

- The entrance channel will be protected against waves and tidal currents.

Disadvantages:

- Possible erosion of the tidal flats at the land-side of the dam.
- The dam reaches into deeper waters. Because of this and because of strong tidal currents a heavy construction will be required and it will be more difficult to construct.

### Alternative 2, variant 1

*Submerged water wall - route I*

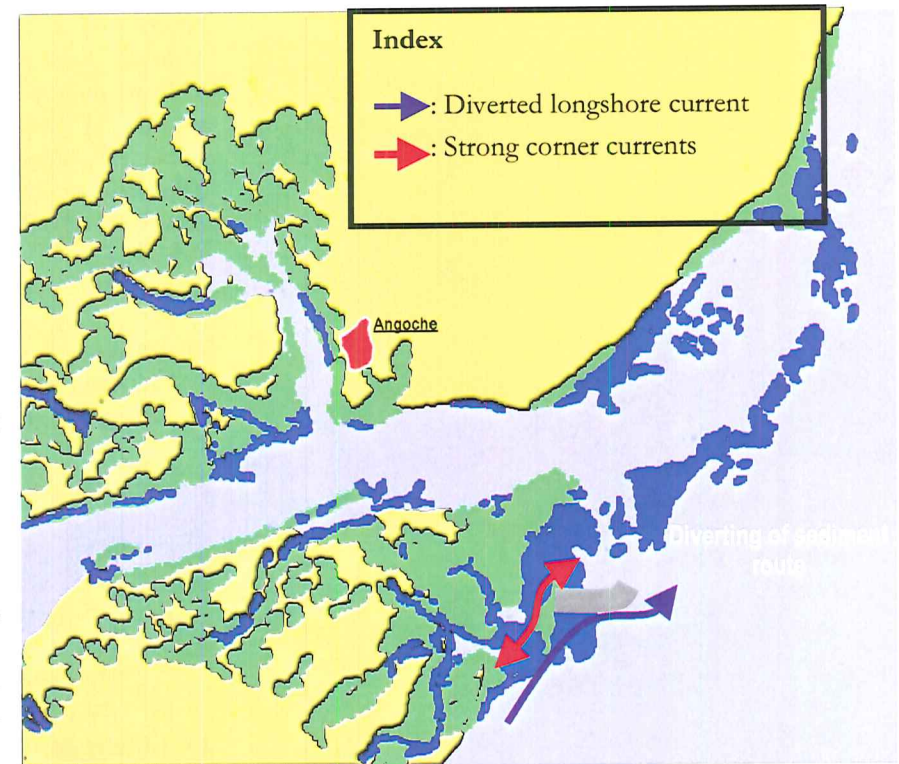
The alternative comprises a submerged water wall. The wall causes a decrease of the sediment in suspension that passes the entrance of the channel. The location of this wall is just south of the entrance of the channel, east of Praia Nova (See figure on page 79). The submerged water wall is positioned parallel to the coast and has a length of 500 to 1000 meters. The wall is made off rocks dumped on the seabed.

Advantages:

- The tidal currents are less strong in the surroundings of route I than of route II, this has a good effect on the navigability of the entrance channel.
- The construction to break the waves is easy to construct and not a lot of construction material or skills is required.

Disadvantages:

- The effects of this solution take a relative long time.
- It is difficult to determine the position of the created deeper entrance of the channel.



Submerged water wall at low tide





Shipwrecks in the port of Maputo



Erosion at Ilha de Busio

### Alternative 2, variant 2

#### *Submerged water wall - route II*

This alternative corresponds with the preceding solution; however the position of the wall differs. The submerged water wall is located just south of the entrance of the channel, south-east of Ilha de Buzio, because the mean long shore current is directed up north.

The wall is positioned parallel to the coast, having a length of 500 to 1000 meters. The wall is constructed by dumping rocks on the sea bed.

Advantage:

- It is a simple construction.
- Construction material and skill are available in the region of Angoche

Disadvantages:

- The effects of this solution take a relative long time.
- It is difficult to determine the position of the created deeper entrance of the channel.

### Alternative 3, variant 1

#### *Dredging – route I*

The solution consists of dredging the old approach channel. A difficulty is that in Mozambique not sufficient knowledge, skills and material are present. This means that it has to appoint a dredging company from abroad, which makes it rather expensive.

Advantages:

- The tidal currents are less strong at route I than route II: dredging route I is more advantageous.
- The desired results are immediately achieved and with accuracy.

Disadvantages:

- The presence of ship wrecks in the outer delta at route 1.
- The presence of heavy sands in the outer delta reduces the dredging capacity of the ship and thus the dredging cycle.

### Alternative 3, variant 2

#### *Dredging – route II*

The solution consists of dredging route II, which is to be used by fishermen.

Advantage:

- The desired results are immediately achieved and with accuracy.

Disadvantage:

- The presence of heavy sands in the outer delta reduces the dredging capacity of the ship and thus the dredging cycle

## Most suitable solutions

All possible actions which can solve the problems within the flow area around Angoche will be narrowed down to three best, most suitable, options. In the next paragraph we will discuss which options are most suitable. Within this discussion there is an interaction between the socio-economic system and the natural system: i.e. which interventions are most suitable depends on how the effect corresponds with the policy of the district of Angoche.

Each of the solutions mentioned in the previous chapter will be analyzed on the basis of the following criteria:

- 1) The total costs
- 2) Protection against erosion of Ilha do Buzio and Praia Nova. As mentioned in the previous chapter this is one of the policies in Angoche's municipality plan.
- 3) The growth of employment due to the project
- 4) Feasibility within the framework of political management. Mozambique as a whole and Angoche in particular, is very poor and undeveloped. Furthermore its bureaucratic management is quite disorganised. Both aspects hamper the feasibility of a civil engineering project in the port of Angoche.

The solutions which are recommended are:

### **Alternative 1, variant 2: Guiding of the ebb stream in combination with decrease of sediment in suspension - route II**

Because it gives protection to certain areas it corresponds with the policy of Angoche district. Constructions are simple. They can be built by local people out of construction material, which can be found in the district. Building the dams provides employment in different sectors. All these aspects make it a relatively inexpensive solution.

### **Alternative 2, variant 1: Submerged water wall - route I**

This solution is less reliable than Alternative 1 variant 2, but it is the most simple and cheapest option. It might not provide so much employment but in a poor and bureaucratic environment like Angoche it is a feasible option.

### **Alternative 3: Dredging**

It is a very expensive solution. But if the World Bank or a private partner would want to invest in the port of Angoche it would be a very good solution to the problems in the entrance to the port: It gives you immediate result, which, within the framework of political management, makes it most feasible. Because of its durability there has to be a partner involved which profits from the port being dredged once in the 5 to 10 years.



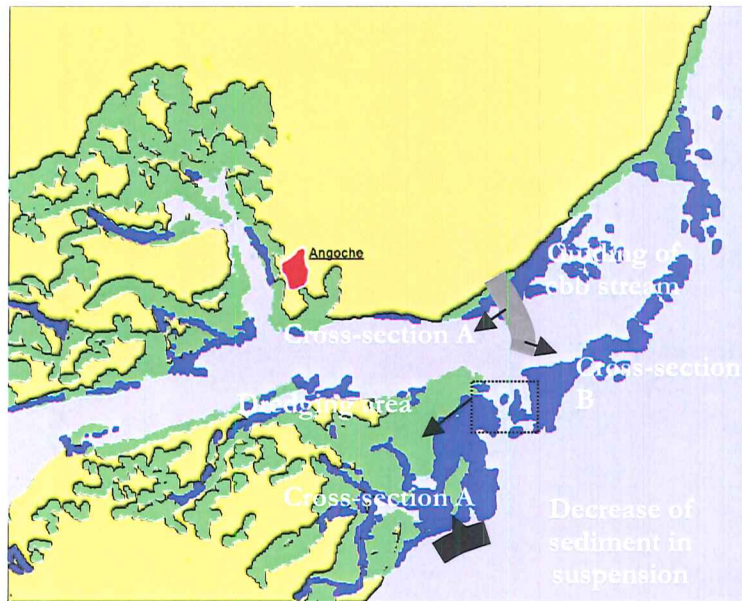
Current users of the estuary



Future user of the estuary?

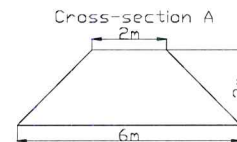


## Appendix A: Costs

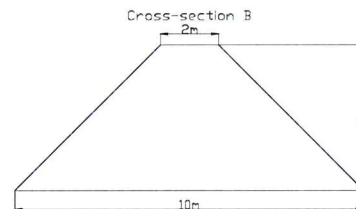


### 1. The dam to guide the ebb stream

The total length of the dam amounts to 1500 meters and is divided in two parts (see figure on the right). Each part with their own cross-section. Cross-section A is in shallow water with a length of 1000m, B in deeper water with a length of 500m. The cost of dump rock is estimated on 750 Euro per m<sup>3</sup> and the cost of concrete is estimated on 1000 Euro per m<sup>3</sup>. Those costs are inclusive labour costs to put them in the right place. Estimation of the cost:



$$\begin{aligned}\text{Surface area} &= 2 \times 2 + 2 \times 0.5 \times 2 \times 2 = 8 \text{ m}^2 \\ \text{Dump rock} &= 8 \times 1000 \times 750 = 6.000.000 \text{E} \\ \text{Concrete} &= 1 \times 2 \times 1000 \times 1000 = 2.000.000 \text{E}\end{aligned}$$

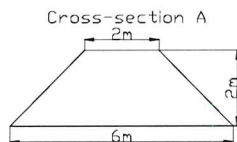


$$\begin{aligned}\text{Surface area} &= 4 \times 2 + 2 \times 0.5 \times 4 \times 4 = 24 \text{ m}^2 \\ \text{Dump rock} &= 24 \times 500 \times 750 = 8.000.000 \text{E} \\ \text{Concrete} &= 1 \times 4 \times 500 \times 1000 = 2.000.000 \text{E}\end{aligned}$$

Total cost in this case is 18.000.000 Euros. The estimation of the cost of new design dam is between 20 and 25 billion Euros.

### 2. The submerged water wall

The total length of the dam amounts to 500 meters with a cross-section A (see figure on the right). The dam consists of dump rocks only. Estimation of the cost:



$$\begin{aligned}\text{Surface area} &= 2 \times 2 + 2 \times 0.5 \times 2 \times 2 = 8 \text{ m}^2 \\ \text{Dump rock} &= 8 \times 500 \times 750 = 4.500.000 \text{E} \\ \text{Total cost} &= 4.500.000 \text{ Euros}\end{aligned}$$

$$\begin{aligned}\text{Surface area} &= 100 \times 200 = 20.000 \text{ m}^2 \\ \text{Volume} &= 20000 \times 4 = 80.000 \text{ m}^3 \\ \text{Total cost} &= 80.000 \times 500 = 40.000.000 \text{ Euros}\end{aligned}$$

### 3. Dredging

Dredging is a temporality solution; this means that it has to be repeated every five a ten years. Mozambique doesn't have her own dredging fleet which makes it expensive. When they start dredging for the first time, a much greater amount of sand is dredged then is necessary to create an entrance for the channel (see figure on the previous page for the dredging location). The extra deep entrance of the channel stays navigable for ships much longer. Calculation of the cost of dredging:

## Part 4: Port design





## Introduction

In the past Angoche, a coastal town in the north of Mozambique served as an important seaport for trading. Nowadays the old port has been desolated. Its function has been taken over by several locations where port activity is taking place on a small scale.

In this report the site with most potential will be considered and further analyzed in order to improve the current situation. The emphasis is on the most important and influential port element to start port development. Revival of Angoche's port could bring an economical and social growth to Nampula province and the district of Angoche in particular.

### 6.4. Case description

Each coastal province of Mozambique is in the possession of a main port for the province. For Nampula this used to be the port of Angoche. Nowadays this role has been taken over by the natural deep port of Nacala. Competing with this port seems impossible, especially when taking into account the development plans of Nacala's port and corridor. This take-over has drastically put limits to the possible future hinterland for the port of Angoche. The poor conditions of infrastructure within the district of Angoche are merely aggravating these limitations.

Nowadays the old seaport has been desolated.

Along the approach channel, several locations can be distinguished where port activity, mostly fishery, is taking place on a small scale: *Porto Nova*, the new port since 1973, a *jetty*, constructed at the edge of town in 1991 and the *beaches* used for simple landing by local fishermen. The services provided at these locations are scarce.

In order to make use of these basic landing stages, the users need to be more or less self-sufficient.

### 6.5. Problem definition

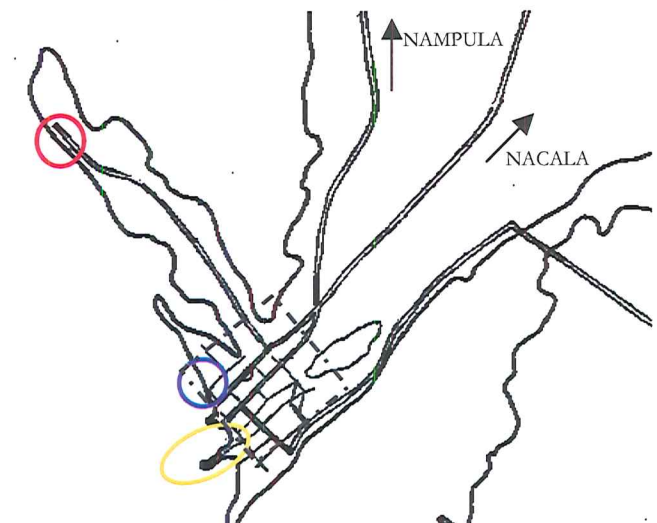
Angoche is in short of a central port. Its port activity is spread over various sites, all in poor conditions and lacking of good facilities and hinterland connections.

### 6.6. Goal of the project

The main goal of the project is the design of a functional port in Angoche, at the site with most potential for port development, comprising the required facilities. Of all possible port functions, the most important one to start port development will be selected and be subject of further investigation.



Port of Angoche



- Encircled in yellow: Porto Nova
- Encircled in blue: Fishing port; beach
- Encircled in red: Jetty
- Dotted line marks the historic city centre

Locations with port activity in the surroundings of Angoche



## 7. Design principles

The design principles have been divided into juridical/political, executive, technical, hydraulic and geotechnical principles. For every principle further subdivision has been made into requirements (R), starting points (S) and assumptions (A).

### 7.1. Juridical and political principles

- RJP1 Land allocation plan (municipal, regional and provincial level)**  
The development of the port has to be in accordance with the land allocation plans/policy of the government of Angoche city, Angoche district and the Nampula province.
- RJP2 Environment**  
The construction of the port has to be in accordance with the environmental rules.
- SJP1 Noise pollution**  
The legislation on the field of noise pollution will not be considered. Local residents will not experience nuisance, seeing that residents are not living in the vicinity of the port.
- SJP2 Trembling**  
The legislation on the field of trembling will not be considered. Local residents will not experience inconvenience, seeing that residents are not living in the vicinity of the port.
- SJP3 Aesthetic**  
No restrictions are held on the field of aesthetics.
- AJP1 Responsibility**  
The legal responsibility regarding the project is in hands of the district administration of Angoche.

### 7.2. Executive principles

- SE1: Economical**  
In the advice the most economic solution will be pursued.
- SE2: Manpower**  
The presence of required manpower is sufficient.

### 7.3. Technical principles

- ST1: Hydraulic construction**  
The hydraulic construction will be dimensioned based on strength, stiffness and stability.
- ST2 Depth approach channel**  
The depth of the approach canal must be at least 1.25 times the depth of the structure.
- ST3 Safety of vessels**  
There should be no berths or hard structures in the stopping line of the vessels, also not beyond the turning circle.
- AT1: Temporary facilities**  
Temporary facilities for navigation or the use of the port are left out of consideration.

### 7.4. Hydraulic principles

#### RH1: Mean sea level

Hydrographic point of reference for the sea level is zero. The mean sea level is +2.4m. In Angoche the fix reference point is the old vessel serving as the quay. The deck of the vessel is +5.08m above the hydrographic point of reference and +2.68 mean sea level.

#### RH2: Tide

Tide	High [m]	Low [m]
Max Spring tide	4.6	0.25
Spring tide	4.24	0.56
Average tide	3.45	1.16
Neap tide	2.89	1.91

#### RH3: Tidal range

The tidal range is determined as follows:

High water:  $3.45 + (4.6 - 3.45)/2 = 4.03 \text{ m}$

Low water:  $1.16 - (1.16 - 0.25)/2 = 0.705 \text{ m}$

Tidal range:  $4.03 - 0.705 = \underline{3.02 \text{ m}}$

**RH4: Meteorological conditions**

Condition	November to April	May to October
Wind direction	NE	SSE
Days of rain	70	36
Rain	212.6 mm/month	35.3 mm/month
Moisture	79.2	78.9
Average temperature	29.4 C	21.2 C

**RH5: Surface of the estuary.**

The surface of the estuary during low water:

Estuary of Angoche	Surface [km <sup>2</sup> ]
The channels	220
The tidal flats	120
The outer delta	75
The total	415

**SH1: Normatively dimensions design ship**

The design ship has the following dimensions:

Length	90 m
Width	11 m
Draft	4.5 m

**SH2: Intensity**

The average intensity of the merchant shipping is determined at 10 (design) ships per month. The smaller fishing boats make use of the port daily.

**SH3: Sea level rise**

Future sea level rise is left out of consideration.

**SH4: Water level rise**

The water level rise due to the wind is left out of consideration

**SH5: Ice and snowfall (see p.61)**

The occurrence of ice and snowfall are left out of consideration

**SH6: The local fishery**

Negative side effects to local fishery activity must be avoided.

**7.5. Geotechnical Principles****AG1: Water pressure**

The water pressure is assumed to be hydrostatic.

**AG2: Coefficient of friction**

However there can be small irregularities in the course of the friction coefficient inside the different layers, these are considered to be homogeneous, and can be neglected.

**AG3: The ground composition of spit of land**

The ground is composed out of sand with a permeability of  $10^{-5}$  m/s, and is considered to be the same in the entire port area.

**AG3: The ground composition of seabed**

The ground is composed out of clay with a permeability of  $10^{-10}$  m/s, and is considered to be the same in the entire estuary.

**AG5: Level of groundwater**

The level of groundwater is estimated to be equal to the water level in the adjacent channel.

The impact of ground water on the water pressure is negligible



## 8. Analysis

By analyzing the processes, which are taking place in a port, a determination of the required functions has been obtained. The necessary facilities are portrayed in a so-called tree structure.

### 8.1. Process analysis

A process analysis has been made by looking at the activities of which is expected the port needs to bear. The following activities have been distinguished for the port area, divided into types of user, namely tourists, goods, customers and port employees.

#### Tourists

- to arrive
  - to transport over sea
  - to transport over land
- to choose an activity
  - to embark
  - to aboard
- to depart
  - to transport over sea
  - to transport over land

#### Goods

- to arrive
  - to transport over sea
  - to transport over land
- to handle cargo
  - to load into ship from shore
  - to unload from ship onto shore
  - to store temporarily
  - to load into transportation modes on land
  - to unload from transportation modes on land
  - to wash
  - to process, e.g. to (re)pack, to bag
- to depart
  - to transport over sea
  - to transport over land

#### Customer/Vessel:

- to arrive
  - to transport over sea
- to make use of a kind of services
  - to supply (tap fuel or water)
  - to load
  - to unload
  - to repair
  - to declare goods
  - to check, e.g. quality or quantity checks
  - to maintenance
  - to berth/rest
- Feed back: to make use of another kind of service
- to depart
  - to transport over sea

#### Port employees

- to arrive
  - to transport over sea
  - to transport over land
- to carry out a service:
  - to repair
  - to maintain
  - to store goods
  - to load goods into ship
  - to load goods into transportation modes on land
  - to unload goods from ship
  - to unload goods from transportation modes on land
  - to check, e.g. customs checking, quality or quantity checks
  - to administrate goods
- Feed back: to carry out another kind of service
- to depart
  - to transport over sea
  - to transport over land

## 8.2. Functional requirements and planning elements

Before entering into planning and design of a port, it is a must to determine the functions of a port, necessary for carrying out the above-mentioned processes and activities, and to understand its organization. The primary functions of a port are:

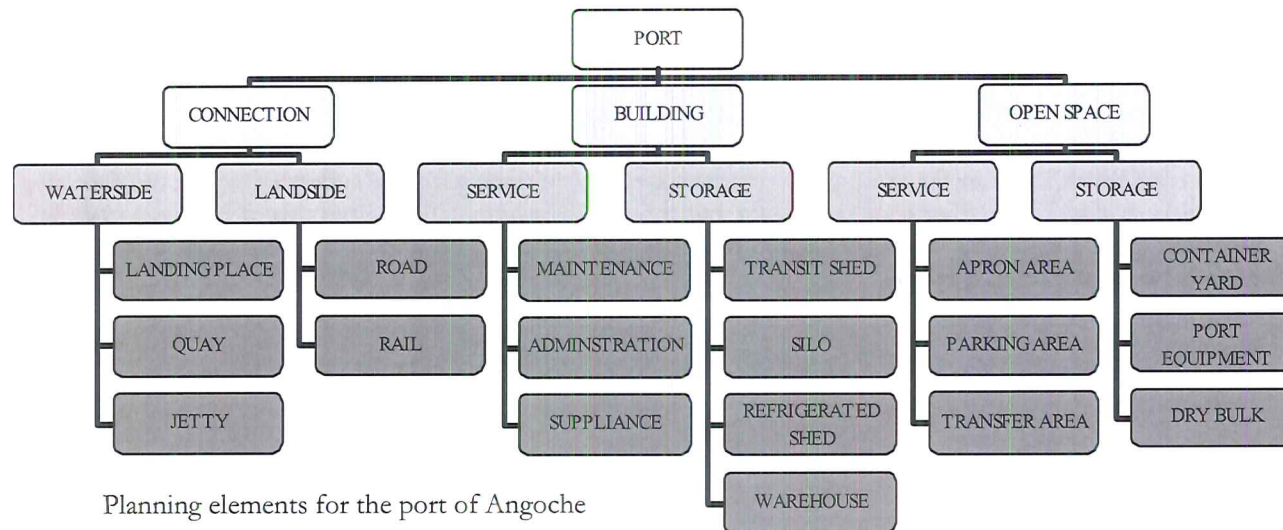
- Traffic function: the port is a nodal point in the traffic, connecting water- and various land modes.
- Transport function: ports are turntables for various cargo flows.

To fulfill its role as a nodal point in the traffic, the following conditions are required:

- The entrance from sea needs to be accessible and safe (front door)
- Port basins and quays, adequate space for maneuvering and berthing of the ships, capacity for handling and storage (sufficient capacity and services in the port itself)
- Hinterland connections depending on the transport function (backdoor)

In Mozambique, the transport function is still the responsibility of the port authority (Service Ports). For this type of port organization a natural hinterland without competition of other ports is a necessity. In Angoche this is not the case, since Nacala is the main port of Nampula province, having a promising corridor. In most Western countries, the responsibility of the (un-)loading and the storage of the goods has been taken over by a stevedore firm.

Bearing in mind the functional requirements, the following planning elements for the port of Angoche are distinguished.



Port of Maputo



Open space, Navique Terminal, Maputo





Connection at waterside, Port of Angoche



Landside connection, Port of Angoche

The different colors mark one level, whereas each level contains functions of the same order. Up to the fourth level has been portrayed. However, on the fifth level a further division can be made, e.g. maintenance buildings can be subdivided into workshop, shipyard and dock.

### 8.3. Relation between functional requirements

To get a better understanding of the relations between the required planning elements and therefore the desired proximity, a relation matrix is a useful tool. The matrix below presents the interaction between the port elements on the third level. The landside connections are not included seeing these will result naturally, due to the fact there is just enough space for one main road in the port area.

		A	B1	B2	C1	C2
A	CONNECTION AT WATERSIDE		1	2	0	2
B1	SERVICE BUILDINGS	1		0	2	0
B2	STORAGE BUILDINGS	2	0		2	1
C1	OPEN SERVICE SPACE	0	2	2		1
C2	STORAGE AREA	2	0	1	1	

0 moderate  
1 normal  
2 strong

Table 3.1: Relation matrix of planning elements on third level

A strong relation exists between the waterside connection structures and the storage facilities. The un- and loading of goods must be efficiently located in the vicinity of storage facilities. The open service space has a strong interaction with the service- and storage buildings, i.e. transfer areas have close connections with the transfer area; apron area has a strong relation with the supply of water and fuel. However, there is a no relation between apron area and the administration office. From this, it becomes clear that the matrix gives a basic idea of the interaction between port elements; it doesn't cover information on the interaction between all port elements.

## 9. Syntheses

### 9.1. Choice of location

It is advisable to develop the port at a site where port activity already takes place, seeing fishermen in particular are reluctant to change. When speaking of the port of Angoche most people refer to Porto Nova (New Port). This port, situated near Porto Velhor (Old Port), arose in 1973 with the sinking of an old vessel, which until today serves as the quay. However, at more locations along the approach channel port activity is taking place. In 1991 a jetty was constructed by the British engineering company Whessoe Projects LTD at the request of the Mozambican government. The local fishermen make use of the beaches for simple landing in the so-called fishing port (see figures on the right and the map on page 87 for locations).

By evaluating and judging the potential sites, a set of four criteria has been formulated: accessibility over land, conditions of the approach route over water, availability of facilities and the possibility of expansion. The first two criteria are considered to be of more importance, and therefore will be valued on a scale of 1 to 8, whereas the other two will be valued on a scale from 1 to 4.

### 9.2. Porto Velhor (Old Port) and Fishing Port

The Fishing port lies at the side of the former, currently, desolated port of Angoche, Porto Velhor. These two locations are being considered and judged as one location, seeing their proximity and share in accessibilities and possibilities.

#### *Accessibility over land*

Both sites are located in the historic centre of Angoche, where the broad avenidas provide a rapid access to the roads towards Nampula and Nacala.

However, the access road to the fishing port is a sandy path.

#### *Conditions of the approach route over water*

At these locations, the width of the channel is sufficient in terms of maneuvering and the required turning circle. The port is only accessible during high tide for smaller fishing boats.

#### *Availability of facilities*

The Fishing Port is in short of an actual mooring - local fishermen use the beach for simple landing - and no supply (water, fuel and electricity) is being offered. The beach is situated in front of a line up of old warehouses and is in the vicinity of other unused storage rooms and buildings.

#### *Expansion possibilities*

The somewhat dilapidated warehouses can be put into use again.



Fishing port



Porto Nova



Jetty (under construction)



### 9.3. Porto Nova (New Port)

Since 1973, Porto Nova is the official new port of Angoche. The port, which has not been continuously operational in the past years, has been officially re-opened in January 2004.



Available area of Porto Nova

#### *Accessibility over land*

Porto Nova is located in the historic centre of Angoche, where the broad avenidas provide a rapid access to the roads towards Nampula and Nacala. On the spit of land, leading towards the quay, an unpaved road in relatively good conditions is present.

#### *Conditions of the approach route over water*

Porto Nova is the closest to the entrance of the approach channel followed by the Porto Velhor/Fishing Port and the remote Jetty. The width of the channel is sufficient in terms of maneuvering and the required turning circle. During high tide Porto Nova is accessible for small fishing boats. The quay falls dry during low tide.

#### *Availability of facilities*

The port consists of merely one quay -a 60 meters long corroded vessel, with a not operating crane- one relatively new steel shed and one old boat house. At the site electricity is present and water and fuel can be obtained if in stock. Near Porto Nova the company Pesca Norte is located, which possesses a small but clean and working fish- and ice factory. Located in the centre of Angoche and therefore in the vicinity of unused buildings and potential storage rooms.

#### *Expansion possibilities*

The relatively new shed and the somewhat dilapidated warehouses can be put into use again.

In the vicinity of the port, PetroMoç -a petrol company- is situated which could provide the needed fuel supply.



Available space to develop on land port facilities (see also page 98)



## 9.4. Jetty

The Jetty was constructed at the edge of town in 1991 by a British Engineering Company. All the required materials and equipment was transported from England to Mozambique for this project.

### *Accessibility over land*

Out of the three, the jetty is the least accessible over land, seeing that it is situated on a peninsula at the edge of the town, with the only access road going right through the dense inhabited quarter Inguri

### *Conditions of the approach route over water*

Near the jetty the channel is considerably less wide, and therefore puts limits to the maneuvering possibilities and required turning circle. In order to come to the remote Jetty many small sailing boats and fishing nets need to be evaded. During high tide the jetty is accessible for small fishing boats and falls dry during low tide.

### *Availability of facilities*

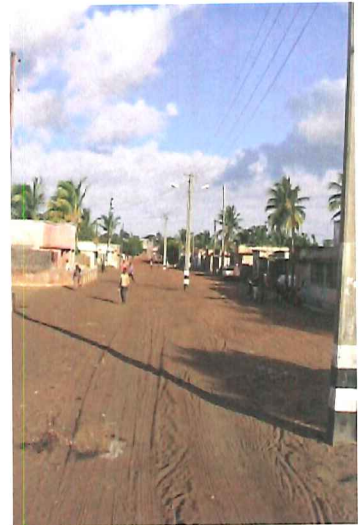
The jetty comprises a 50 meters long floating pontoon connected to land by means of a moveable bridge. An important advantage of the floating pontoon is the lesser burden working on the mooring, in terms of water pressure, soil forces and forces caused by siltation.

The pontoon is constructed in non stainless steel, and has no crane though the technical drawings show the reserved room for one. With the building of the jetty a petroleum platform was planted. However, never used. At the site water can be obtained.

Most recently constructed, the Jetty appears to be in the best state, despite the visible oxidation of the steel pontoon.

### *Expansion possibility*

In the surroundings of the jetty sufficient unused area is present. However, the fact that the jetty is situated on a peninsula and in the quarter of Inguri, put limits to its expansion possibilities.



Accessibility over land, Jetty

## 9.5. Site with most potential for port activity

The site with most potential for port development is obtained by means of a multi criteria analysis. For each location is given to what degree it possesses the required criteria on a scale from 1 to 4 and for the criteria's concerning the accessibility over land and the conditions of the approach route over water from 1 to 8, whereby 4 respectively 8 is the maximum score.

Criteria\Location	Fishing port/Porto Velhor	Porto Nova	Jetty
Accessibility over land	5	6	3
Conditions approach route	2	6	3
Availability of facilities	1	2	2
Expansion possibility	1	2	2
<b>Total</b>	<b>9</b>	<b>17</b>	<b>10</b>

Table 4-1: Multi Criteria Analysis on potential site for port development

With these obtained insights, together with the outcomes perceived from the multi criteria analysis, it can be concluded that Porto Nova has the most potential for port development.



Accessibility over water, Jetty



## 10. Port Planning

### 10.1. Cargo Forecast

By assessing the trade flows from which the port of Angoche is expected to process, a division has been made into the present situation and future prospects. These figures directly show that no queuing theory needs to be used to determine that one berth is sufficient.

The *present situation* has been reviewed: what kind of facilities are missing and what kind of improvements need to be done in order to handle the current cargo flow.

Estimation of the current cargo flow:

Type of cargo	Volumes of cargo	Ship size (L x W x D)	Intensity
Fish	30 ton	14 x 5 x 2.5	monthly
Timber	800 ton/1000 m <sup>3</sup>	40 x 10 x n/a (flat bottom)	potential
Cashew nuts	30 containers/year	-	potential
Consumer goods	-	-	potential

Table 5-1: Current cargo flow

Nowadays, timber, cashew nuts and customer goods are transported over land by truck. These goods could be transhipped instead, if the port of Angoche will be upgraded and will be used more efficient.

For *future prospects* an estimation can be made by looking at the trade flows of the port in its blooming years, and by making an extrapolation of actual cargo flows. On future cargo forecast will not be elaborated in this report. However, one must take into account planning elements needed for future expansion, such as a refrigerated shed, a storage yard and a second mooring. Therefore it is aimed to reserve as much space as possible for future expansion.

### 10.2. Port elements

The port elements as portrayed in *paragraph 4.2: Functional requirements and planning elements* need to be reviewed for both the present and future situation. In doing so, some elements are refrained from and others are united.

For the present situation, the following port elements are distinguished:

Port element	Includes	Area (m <sup>2</sup> )
1. Storage rooms	warehouses, sheds	800
2. Mooring	apron area, supply	360
3. Transit shed		800
4. Maintenance	shipyard; dock	50
5. Parking area		60
6. Administration		60

Table 5-2: Port planning elements, *present situation*



Consumer goods, Nampula



Storage room, Port of Maputo

Notes:

- Apron area and supply are included in the mooring. The reason for this, is the fact that an apron area is a fixed area on the quay and is solely mentioned for completeness, whereas supply is more a service provided at the quay.
  - A shed is currently present at the entrance of the port. However, a second transit shed or transit area closer to the quay can be useful.
  - Sufficient storage room is present at the site: steel shed, unused warehouses.
- For future prospects as much area as possible needs to be reserved. Probably these areas will be used for mostly storage.

### 10.3. Port Layout

In order to come to an efficient port layout, it is necessary to have a good understanding of the relationships between the different planning elements: storage rooms, mooring, transit shed, building for maintenance, parking area and administration building

To gain this insight, different kind of graphical tools are applied, such as a relation matrix, a circle graph and a bubble diagram.

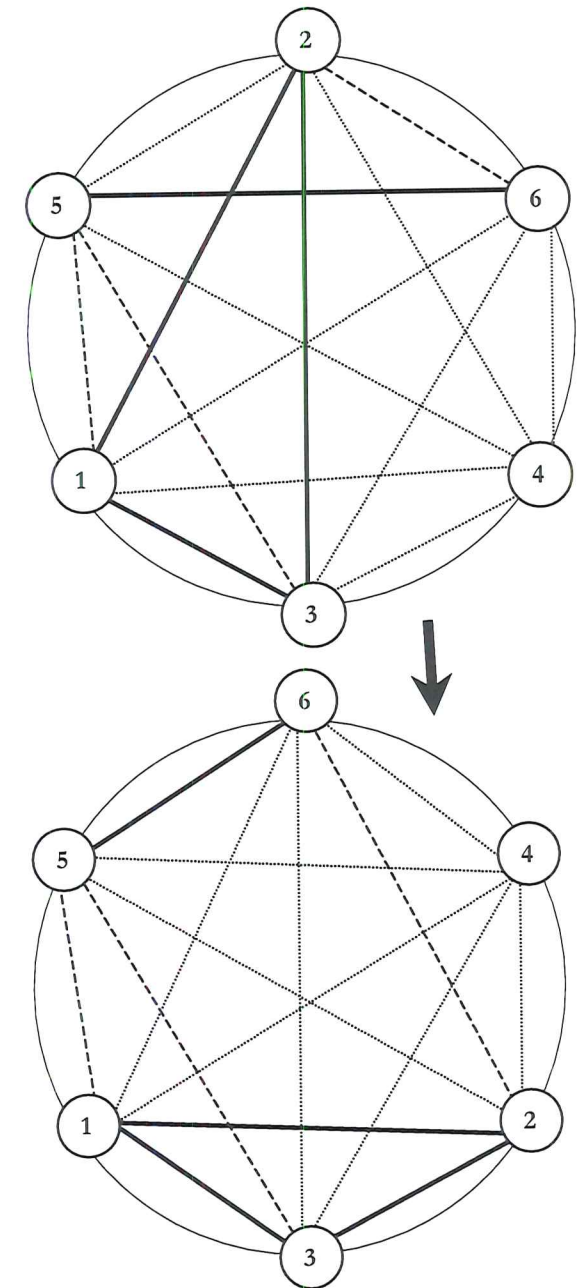
In *paragraph 4.3: Relation between functional requirements*, the relation matrix gives the positioning of the elements, judged in accordance with strength of relation to other elements: moderate, normal or strong.

With this gained information, the port elements with their relations are orderly portrayed in a circle graph, to get a better insight in an effective positioning.

At first, the elements are positioned randomly on the circle; the lines indicate the strength of interaction, whereby the thickest line stands for the strongest relation. Then the elements are moved in such a way that elements with a strong interaction are put near to each other.

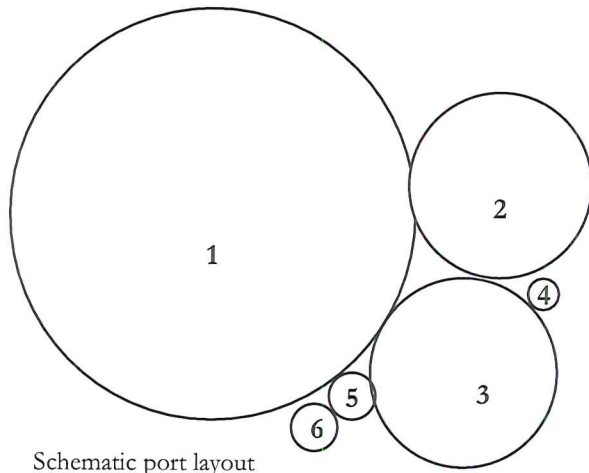
*Clarification:*

- 1 Storage rooms
- 2 Mooring
- 3 Transit shed
- 4 Building for maintenance
- 5 Parking area
- 6 Administration building



Circle graph of the port elements and their relationships





Schematic port layout

A schematic port layout is achieved by giving the port elements a size, proportionate to its volume, and by moving them to each other in accordance with the strength of relationships between the different elements.

Seeing that there is only one access road present and room for in the port of Angoche, the connections do not need to be investigated before entering into the designing of the port layout. These will follow out of the positioning of the port elements in the existing port area.

#### 10.4. Layout of Porto Nova

With these graphic tools a basic port layout is obtained. The key element of the port, namely the mooring, is in very poor condition. For the development of the port of Angoche an improvement of the mooring is priority number one.

At the site sufficient storage room (marked in blue) is present, not all in good conditions.

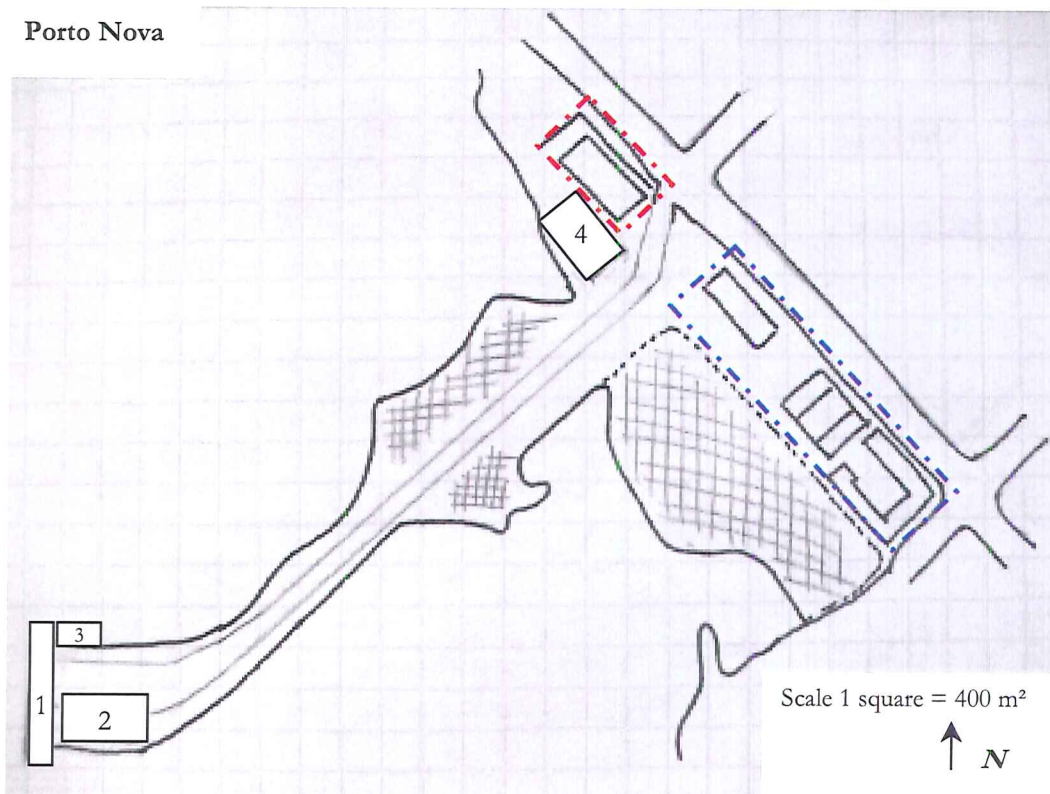
The cross-hatched areas point out the area with unsuitable underground for construction and at the red marked area a sports field is situated. These areas must be left out of consideration.

The mooring and transit shed are positioned in such a way that the processes of loading and unloading are efficiently located close to each other. This means saving of time, distance and effort.

The administration building and parking area are situated next to each other; no vehicles of users and visitors of the port are allowed to drive in the port area. The visitors or users must report themselves at the administration office frequently or have to ask for information at the entrance of the port area; therefore these two port elements are located next to each other and near the entrance.

The layout obtained for Porto Nova serves as a foundation for the positioning of the port elements.

Porto Nova



Basic port layout for Porto Nova

1. Mooring
2. Transit shed
3. Maintenance building (dry dock)
4. Administration and parking area

- - - - - Sport field
- . - . - Storage rooms, include steel shed and old warehouses

## 11. A new mooring

### 11.1. Two alternatives two designs

Two main designs have been distinguished for the port of Angoche: one basic alternative '*minimal rehabilitation*' and one prosperous alternative '*port to Nacala*'. For these two alternatives the port layout, as presented in paragraph 5.4 can be applied, seeing it is based on most efficient positioning of the port elements.

The *minimal rehabilitation* consists of the adjustments necessary to maintain the functions the port presently bears, such as the handling of the fishery. And those the port may be performing in the nearby future, such as the handling of cashew nuts and customary goods. Even if tourism is coming up, the minimal design will be sufficient. However, a mooring for tourists will be constructed in de Old Port. In this way a separation of port activity is obtained and in addition, the Old Port forms an interesting starting- and ending point for tourists. More adjustments in alternative '*port to Nacala*' have been found necessary when a private investor shows interest in Angoche. The Irish company Kenmare Resources has been used to clarify this scenario. Kenmare has initiated the 'Moma Titanium Minerals Project'. In the vicinity of Moma, between the coastal towns of Angoche and Quelimane, large deposits of titanium minerals are to be gained by this company. Within this, Angoche could function as a logistic centre for Kenmare Moma.

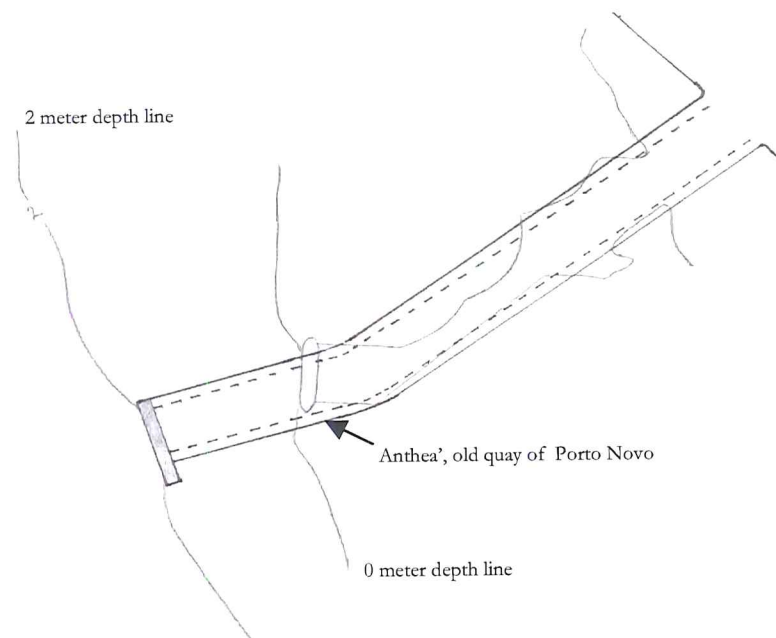
In this report the alternative '*port to Nacala*' will be further outlined. For this design a new mooring construction is considered to be necessary. Presently the quay is located at the ebb streamline. In order to allow vessels, with dimensions of the defined design ship (l x w x d = 90 x 11 x 4.5m), to make use of the port, the spit of land needs to be extended for 100 meters, up to the two meters depth line and has overall latitude of 40 meters. It is observed that the waterfront structures can be positioned up to the two meters depth line, and no further, whereas the ebb stream and the field of currents will be influenced significantly.

The design comes in combination with dredging: 3.5 meters is necessary to allow larger vessels to make use of the port.

### 11.2. Waterfront Structures

Different types of waterfront structures are distinguished and criticized for the port of Angoche. The choice of the appropriate construction is based upon its:

- *Feasibility*: availability of skills, equipment
- *Constructive qualities*: strength and weaknesses of the structure
- *Durability/Flexibility*: bearing in mind the existing tendency to transship in containers

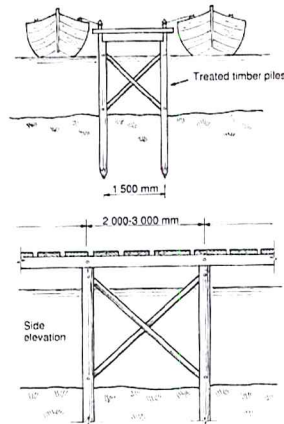


New design of Porto de Angoche

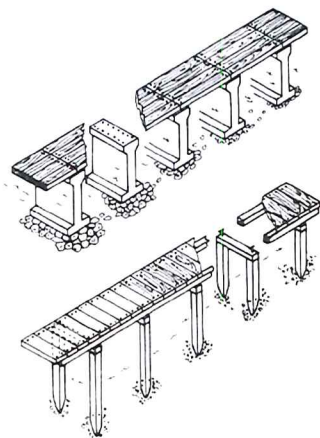


Current waterfront structure, Port of Angoche





Timber-finger jetty



Two types of Timber-finger jetty

## 1 Piers

Piers are characterized as structures with no ground- and water turning function and have the possibility of 'building over': slopes can be ignored, seeing that the waterfront construction is build over the slope.

### 1A Jetty on piles

From the not extended old spit, a pile-supported pier will be constructed, up to the two-meter depth line. Parallel with this line, a pile-supported platform will be placed.

*Options:* T-head pier or L-shaped pier.

*Material:* construction in steel, concrete or timber

*Feasibility*

- Labor intensive
- The materials/equipment and skills to construct the jetty are limited; driving piles can cause for difficulty

*Constructive qualities*

- Piled structure is suitable in mangrove areas, very soft seabed.
- Relatively fragile structure; applicable in calm areas
- Stable slope necessary
- Not possible to carry heavy loads (containers), therefore restrictions are put on the possibilities of the usage of port area. Or a dense field of piles needs to be constructed to carry the heavy loads.
- Free passage of the waves improve port performance

*Durability:*

- Restricted flexibility; difficult to adjust with a change of usage of pier, an increase of loading afterwards is practically impossible.
- Special measurements are necessary to intercept horizontal loading

### 1B Floating pier with Access Bridge

The floating pier is constructed out of several large pontoons joined by pivots. The floating pier accommodates vessels and cargo handling equipment, and provides space for traffic (cargo and passenger).

The bridge provides access at any water level: access bridge and floating docks have no permanent slope. The bridge is supported by piles.

*Options:* T-head pier or L-shaped pier

*Materials:* construction of bridge and pontoon in steel or concrete.  
construction of piles in timber or concrete

### *Feasibility*

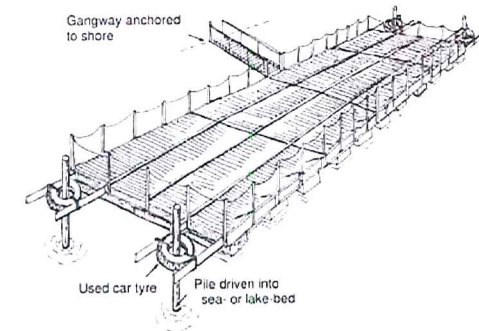
- No good knowledge of and experience with floating structures is present
- For pile driving: skills and equipment are limited

### *Constructive qualities*

- Suitable in areas with large tidal variations
- Special measurements are necessary to intercept horizontal loading
- Minimal intervention in the natural conditions, discharge and sediment load affect the geometry of the river channel, is achieved by appliance of a floating structure.
- Not possible to carry heavy loads (containers), restrictions are put on the possibilities of the usage of the port area.
- Free passage of the waves improve port performance

### *Durability:*

- In corrosive environments, floating piers cause for relatively high operating and maintenance costs.
- Difficult to adjust with changed usage of pier and therefore changed loading
- Changes in water level do not hamper the (un)loading



Floating platform landing

## 2 Quay Walls: Gravity and pile supported walls

Quays may either be solid structures or on piles. Gravity-stabilized structures derive their stability primarily from their weight, combined with the interaction of the structure surfaces with the soil. The cellular structures will be left out of consideration, seeing structures constructed in mainly steel are not desirable in a salt environment.

### 2A Caisson Structure

A caisson structure consists of large, prefabricated reinforced concrete units. The caissons are either lifted by crane or floated into their position; due to their stability during transportation over water larger dimensions of the caissons are demanded. For both types of transport, the intention is to design the caissons with minimal weight.

*Options:* Fill caisson with sand, water or other material, or construct caissons with internal walls in order to increase their weight and stability, or a combination of both adjustments

*Materials:* Caissons of reinforced, prefabricated concrete elements

### *Feasibility*

- Skilled manpower is a necessity; but no good knowledge of and experience with caissons is present (fabrication in docks – transportation – positioning is all labor intensive and requires skilled manpower)

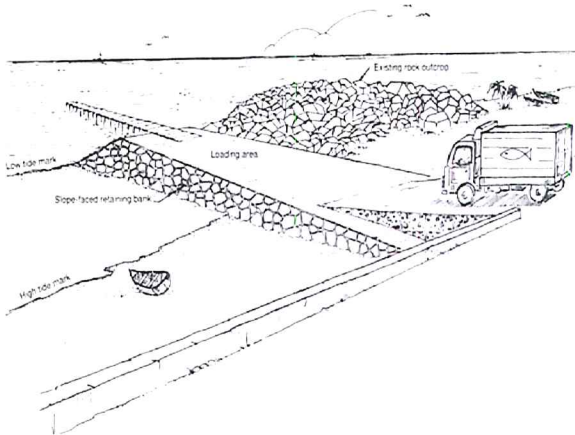
### *Constructive qualities*

- Possibility to carry heavy loads

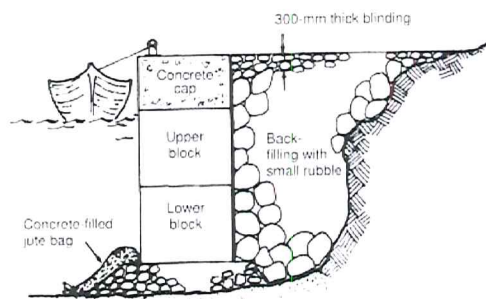


Caisson





Tidal Jetty



Cross-section Block structure

- Rocky/sandy underground or a prepared foundation bed is a necessity. Caissons are heavy structures and exert relatively high pressure on the foundations soil.

*Durability:*

- No difficulty to adjust with changed usage and therefore changed loading on quay; nearly insensitive for changes of loading
- No special measurements are necessary to intercept horizontal loading
- Well-constructed caisson structure gives little difficulties in the future (reliable)

2B Block Structure

Block structures are the oldest type of bulkhead structures.

*Options:* concrete blocks, either solid or hollow, of various sizes and shapes.

*Materials:* concrete, granite

*Feasibility*

- Simple construction; no skilled manpower or experience with block structures is required.

*Constructive qualities*

- Possibility to carry heavy loads
- Suitable for sandy or rocky seabed; block wall structures are quite heavy and exert relatively high pressure on the foundations soil

*Durability:*

- No difficulty to adapt with changed usage and therefore changed loading on quay
- No special measurements are necessary to intercept horizontal loading
- Few maintenance is required

2C L-wall Structure

*Materials:* (prefabricated) concrete.

*Feasibility*

- Labor intensive.
- The materials/equipment and skills to construct and position the L-wall are limited.

*Constructive qualities*

- Possibility to carry heavy loads
- Suitable if bearing soil is not too deep situated

*Durability:*

- No difficulty to adjust with changed usage and therefore changed loading on quay
- No special measurements are necessary to intercept horizontal loading

## 2D Pile supported wharves

*Materials:* concrete and timber.

### *Feasibility*

- Skilled manpower, experience and equipment are necessary for pile driving, these are limited.

### *Constructive qualities*

- Suitable for soft clay ground in mangrove area.
- Free passage of the waves improves port performance.
- Suitable in regions with substantial seismic activity (vertical pile-construction).

### *Durability:*

- Average sensibility for increase of loading
- Heavy loading on quay demands dense field of piles; could function as a fence
- Special measurements to intercept horizontal loading
- Nearly no deformations or difficulties due to dredging work.

	Feasibility	Constructive qualities	Durability	Score
1A	1	2	1	4
1B	1	2	1	4
2A	1	3	5	9
2B	5	1	5	11
2C	2	3	4	9
2D	3	4	4	11

Table 6-1: Multi Criteria Analysis waterfront structures

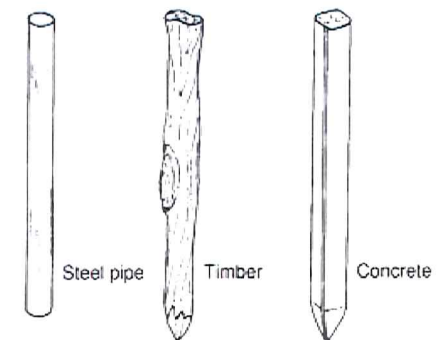
Most suitable waterfront structures for Porto Nova are the Block wall and the pile supported quay/short pier. The important advantage of the Block wall is its durability and resistance for heavy loading and no problems will occur with an increase of loading. The main disadvantage is the unsuitable underground in Angoche's mangrove area: soft clay.

The important advantage of the pile-supported quay is the fact that piles are driven up to the bearing force soil. A marginal note is the lack of information of the soil: depth of the soil with sufficient bearing force is unclear; driving long piles is not without any risk. It might be more economic to apply soil improvement. As a guideline the depth of the piles of the constructed jetty in Angoche is taken: ca. 5 meters is necessary.

The decisive factor in the choice of the waterfront structure is its durability. A block wall will not sustain in a mangrove area. Therefore the pile supported pier has been chosen, seeing the presence of weak soil. The piles can be constructed out of concrete, steel or timber. Steel is a rare material in the region of Angoche with relatively high operation and maintenance costs (durability is not sufficient in salt



Pile supported wharf



Three types of piles

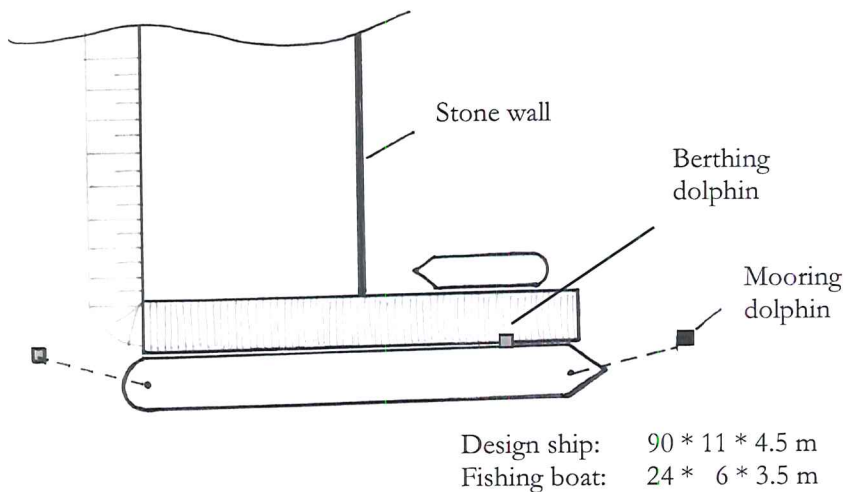


environment). Reinforced concrete is a durable material, but has a relatively high weight and is less economic than timber. Chosen is to construct the piles in timber, due to its high availability, relatively low weight (advantage during construction) and relatively low costs.

### 11.3. Structural Design

The design of the short pier constitutes a timber deck supported by timber piles.

Before determining the loading on the construction, the global dimensions, characteristics of the material(s) and the amount of piles are outlined.



*Layout of the new port*

#### *Material used*

Piles and deck are constructed in tropical hardwood OPEPE

Characteristics of OPEPE:

Official name:	Bilinga (family name: Rubiaceae)
Durability class:	I (lifetime over 25 years)
Weight: (kg/m <sup>3</sup> ):	1025
Compressive strength (N/mm <sup>2</sup> ):	61
Elasticity modulus (N/mm <sup>2</sup> ):	13400

OPEPE is a common used material for waterfront structures. The timber, originally from West Africa, is available and distributed to Mozambique.

#### *Dimensions global*

##### Deck

- Length (m): 80
- Wide (m): 10
- Height (m): 0.5 (construction height)

##### Piles

The length of the piles are based upon the height necessary for waves to have a free flow underneath the deck (no wave swells against the deck), taking into account the depth and underwater keel clearance of the design ship, dredging work and tidal range.

- Length (m): 16 (5 meters driven depth)
- Cross section (m<sup>2</sup>): 0.40 \* 0.40
- Volume pile (m<sup>3</sup>): 2.56

Soil

Assumed grain pressure (kN/m<sup>2</sup>):

500

Bearing force one pile (kN):

$$F = A * \sigma = 0.4 * 0.4 * 500 = 80$$

### 11.4. Load-requirements

The loading on the structure is divided into vertical loads and lateral loads

#### Vertical Loads

The vertical loads determine the amount of piles required for the piled pier structure.

##### Dead Load

- Deck (not a massive structure, assumption 70% is timber)

Volume of deck (m<sup>3</sup>):  $V = h * l * w \rightarrow 70/100 * 0.5 * 80 * 10 = 280$

Force deck (kN)  $F = V * \rho * a \rightarrow 280 * 1025 * 9.81 = 2.815.470 \text{ N} = 2816$

- Piles

Mass pile (kg):  $m = V * \rho \rightarrow 2.56 * 1025 = 2624$

Dead load pile (kN):  $F = m * a \rightarrow 2624 * 9.81 = 25742 \text{ N} = 26$

Bearing force, dead load of pile included (kN):  $F = 80 - 26 = 54$

##### Variable Load

Calculation with either loads due to humans or crane load, not necessary to take both into account, seeing the loads will not occur simultaneously

- Human

Human Load (kN/m<sup>2</sup>):  $\sigma = 4 \text{ kN/m}^2$

Force (kN):  $F = \sigma * l * w = 4 * 80 * 10 = 3200$

Amount of required piles:

Vertical load / bearing force pile  $\rightarrow (2816 + 3200)/54 = 112 \text{ piles}$

- Crane

Characteristics mobile Crane:

Length (m) = 6.5

Width (m) = 2.5

Force due to weight (kN) = 40

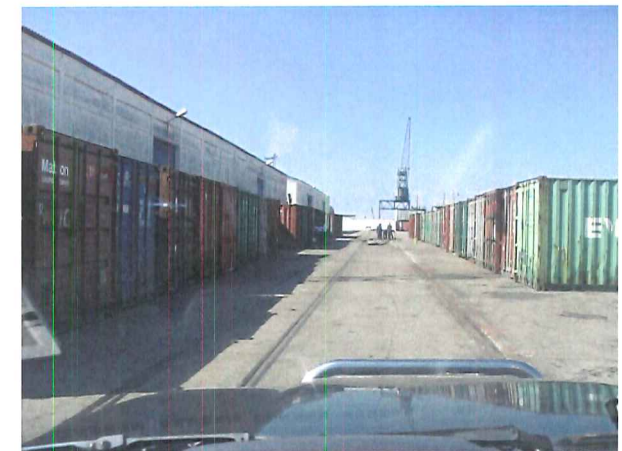
If crane force is divided over two piles, then bearing force of pile (kN):  $F = 54 - 20 = 34$

Amount of required piles:

Vertical load / bearing force pile  $\rightarrow 2414 / 34 = 71 \text{ piles}$



Typical terminal equipment, Port of Maputo



Containers on quay, Port of Maputo



Deck must be supported by 112 piles, with each pile having a bearing capacity of 54 kN  
To obtain a good overview of the arrangement of piles during construction of the jetty, 120 *piles* are placed on a 2 to 4 meters grid, resulting in 3 rows of 40 piles.

### **Lateral Loads**

#### Docking impact

Dependent of velocity and angle of approach of mooring vessels

#### Forces from moored vessels

Caused by currents and wind

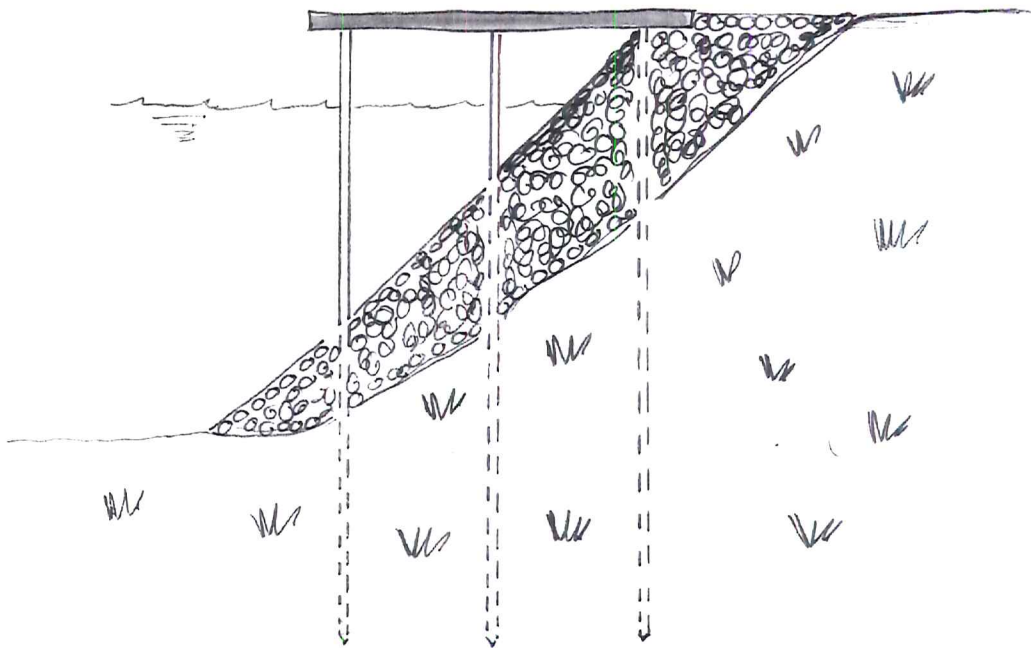
For the two above mentioned lateral forces a different mooring system is required, seeing a pier is not capable to carry them. For larger vessels two berthing dolphins are applied. The berthing dolphins are separated from the jetty, are somewhat elastic and are capable of carrying the lateral forces caused by the mooring and the moored larger vessels; for the smaller fishing boats lateral loads are carried by a fender system.

#### Forces on pier

Caused by wind

Caused by cranes, vehicles, due to stopping of crane/vehicle and wind

To carry the forces on the pier caused by wind and transportation modes, certain 'strong points' in the pier are required. In longitudinal direction on rows A and C and in every transverse direction braces are applied.



*Cross sections of the piles short pier*

## Timber deck

The timber deck is constructed out of treads, planks, stringers, pile caps and piles.

Dimensions of deck-elements are:

Pile cap (l*w*h):	10.000*400*400 mm
Stringers:	10.000*400*125 mm
Planks:	5.000*200*50 mm
Treads:	5.000*180*40 mm

In this order the loads will be carried to the bearing soil. From treads and planks the forces are brought to the stringers, from there these forces are divided over the piles, and through the piles the loading is carried by the bearing soil.

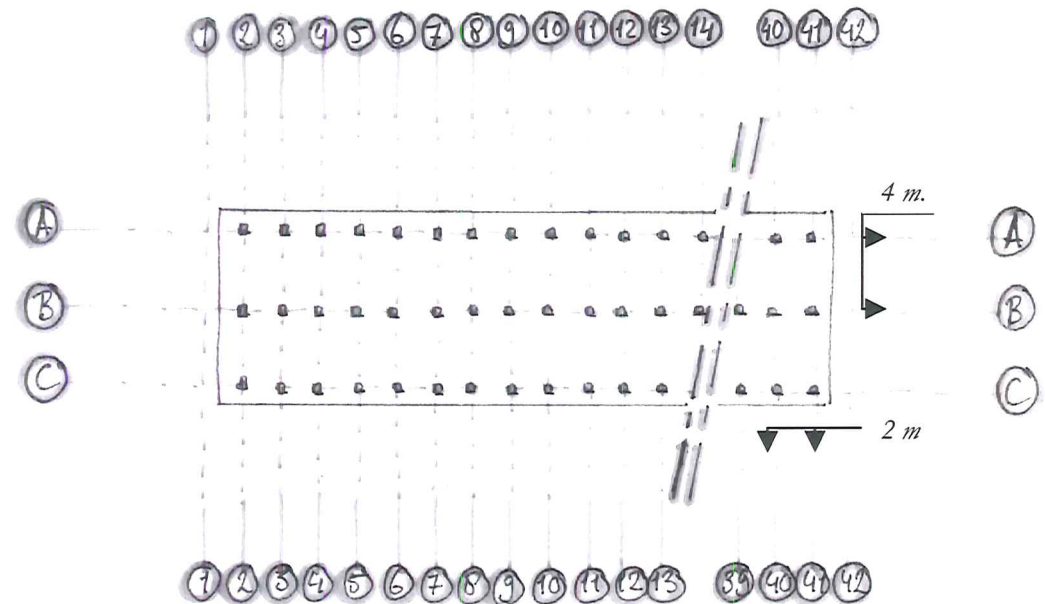
Comments on construction deck:

- (1) Caps: single piece timbers across the tops of the piles; the caps will be strapped to piles.
- (2) Anchorages for deck fittings. Bollards and cleats should be anchored to decks and piling by using spiral-drive drift bolts and metal straps.
- (3) Deck planks and treads. Treads are required in deck for truck and crane loading.
- (4) Bridging. Place solid bridging between stringers over all pile caps.
- (5) Stringers. These stringers will bear on full widths of caps and should lap adjacent stringers.

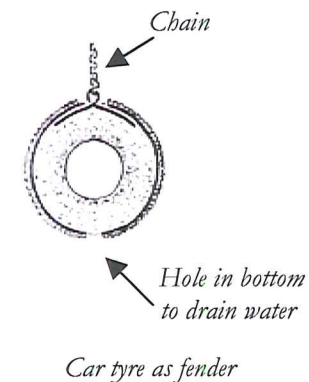
## Fender system

The principal function of the fender system is to prevent the vessel or mooring structure from being damaged during the mooring process and berthing periods. Forces during the vessel's berthing or anchoring may be in the form of impact, abrasive action from vessels, or direct pressure. These forces may cause extensive damage to the ship and structure if suitable measurements are not employed to counteract them.

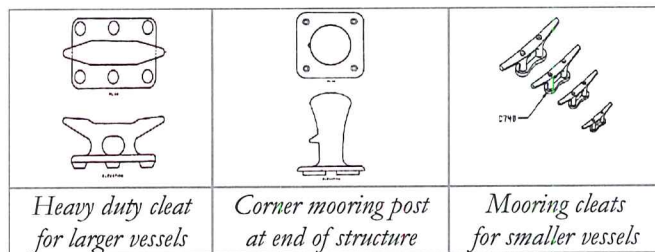
Old car tyres will be used as individual fenders, which is the oldest and cheapest form of simple fendering. To prevent the suspending chain from chaffing against a vessel's side, a 20mm diameter bar hanger should be formed and inserted through an incision at the crown of the suspended car tyre. The tyre fender thus presents a clean soft rubbing surface even when compressed against the boat's side. The tyres are positioned every 4 meters.



Positioning of piles on a 2 to 4 meters grid



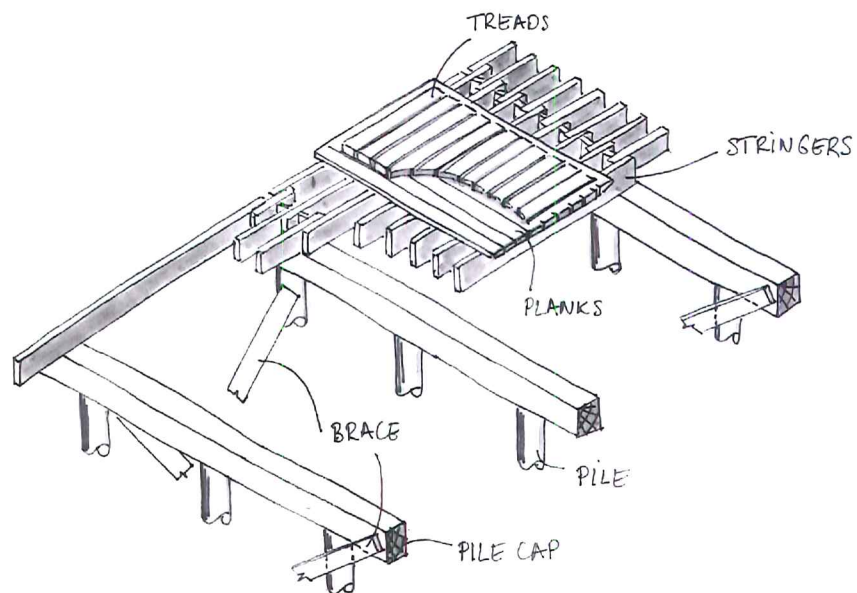




### Mooring devices: cleats, bolder and mooring post

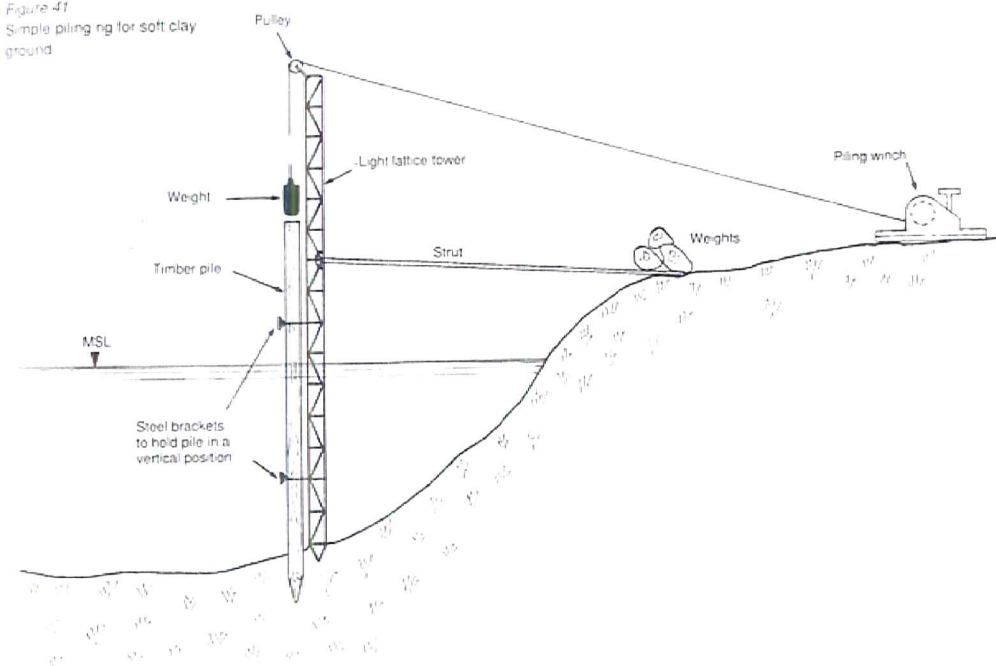
An arrangement of mooring devices to service both small and large vessels is required. Heavy duty cleats are used to accommodate the larger vessels; simpler mooring cleats for the smaller vessels.

Mooring devices



Timber deck

Figure 41  
Simple piling rig for soft clay  
ground



Simple piling rig for soft clay

## Way of building

The timber piles are driven into the soft soil using a pile driver, a simple dredging rig, on a standard 4 to 2 meters grid. Once the piles have been driven into the ground, the shore side should be filled in with coarse quarry material as shown in the cross-section to increase the stability. All the timber used is treated against borers and all metal fittings are galvanized steel. Only countersunk screws and bolts are suitable. Nails should not be used in any part of the deck, due to the fact that when nails corrode they snap suddenly without any warning.

The spit of land is constructed out of clay soil, found in the area of Angoche. At one side of the dike, a stone wall is applied for stability and gives possibility for the berthing of smaller vessels as well.

## Costs

In principle costs can be qualified based upon different key figures, such as volume (m3), surface area (m2) of structure or based upon its users.

For the final design a more detailed estimations for the costs is required. Therefore the short pier is divided into the following elements:

- timber piles
- timber deck
- mooring dolphins
- mooring devices
- fender system
- spit of land

The costs are determined based upon the required quantities and unit prices for the construction of these elements.

Elements	Quantity	Volume/Numbers	Unit price	Price (euro)
Timber piles	m3 timber	310 (=120 * 2.56)	935 / m3	289.850
Timber deck	m3 timber	280	935 / m3	261.800
Mooring dolphins	m3 timber	30	935 / m3	28.050
Mooring devices	per device	70	30	2.100
Fender system	per tyre	50	-	-
Stabilization slope	m3 quarry material	1100	70 / m3	77.000
Spit of land	m3 clay	32000	-	-
Costs elements	-	-	-	658.800
<b>Total costs elements short pier</b>				<b>724.680</b>

Table 6-2: Costs per element



Porto Velhor, in front of the Capitania, Angoche (water side)



Porto Velhor, in front of the Capitania, Angoche (land side)





Current transit shed, (outside)



Current transit shed (inside)

The costs for the lengthening and construction of the spit of land (which will serve as an access road to the mooring) have been omitted. Reasons are the fact that there is no shortage of clay in Angoche, and that the clay can easily be gained in surroundings. The same holds for the old rubber car tyres, functioning as the fender system.

The constructions costs, e.g. rent for equipment, payment of manpower and installation of services (water supply, electricity) are not included in this calculation. However, when taking these costs in account the total costs for construction of the short pier is estimated on **800.000 euros**.

## 12. Feedback and recommendations

In order to come to a more detailed design for the port in Angoche, more reliable information on the soil of seabed is required. Is a piled construction the most suitable structure or is soil improvement a more economic solution?

In addition, more research on future potentials for the port is desirable. Is there a zest for investing in the development of the port in Angoche? Will the cashew industry revive in such a way, that transshipping of cashew nuts will be more economic than by road; will the transshipping of timber become more profitable; and will the transshipping of fish increase? These potential usages and rehabilitation opportunities should be guided by a (foreign) party to control and exploit these opportunities.

## 13. Conclusion

Improvements of the infrastructure are a must, in barely accessible Angoche. Roads are badly maintained; the port is in poor condition and is not frequently being used. Nowadays there is a preference for the transportation of goods by road. Although transshipping of goods could be more economic and efficient.

Today, the port is being used by mainly one fishing company, and occasionally for the transshipping of timber. To maintain this port activity minimal measurements are necessary, seeing that the old vessel functioning as the quay is in very bad condition. However, there exist potentials for the port of Angoche: Investors might become interested in Angoche, a rise of tourism, opening of more cashew factories and increase of the market in cashew nuts and the increase of transshipping timber. When these opportunities develop in such a way that the port needs to be accessible for larger vessels and handling of larger amount of cargo must be made possible, then the more elaborate alternative 'port to Nacala' is suitable. For this alternative a *piled supported short quay* has been dimensioned. The structure consists of a timber deck supported by timber piles, and is in combination with dredging work- made accessible for both small and larger vessels.

It is a must to control and exploit the upcoming potentials in Angoche. In this way, a revival of the port can be the desirable outcome.

# Part 5: Conclusions





# 1. Conclusions

## 1.1. Introduction:

In the '70's the port of Angoche, in that time still called Antonio Enés, was visited by more than 270 ships a year. Large amounts of cashew, sisal hemp, cotton, coconuts, peanuts and prawns were exported to all over the world, while all sorts of luxury goods were imported from Europe and Asia. The ships, entering during the high tide, moored in deeper parts of the channel in front of the 'Capitania', where they were (un-)loaded by more than a 100 small barges. The independence obtained in 1974, followed by 20 years of civil strife, chased away the traders and their commerce. Nowadays, the only port activity is carried out by small fishing boats.

## 1.2. Problem analysis:

**Socio-economic system:** Angoche is an infrastructural island; this detains every possible economic development which is needed to solve everyday problems such as unemployment, education and health issues. New infrastructure can either be road or water.

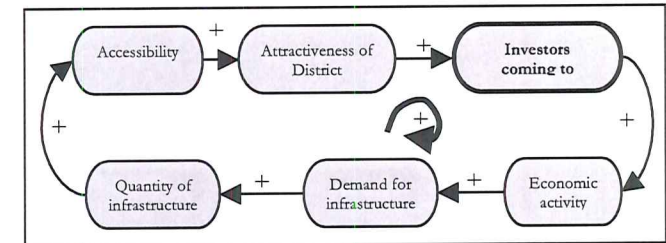
**Port:** Angoche is in short of a central port. Its port activity is spread over various sites, all in poor conditions and lacking of good facilities and hinterland connections. The current location of Porto Nova is most suitable for port development since it has the best accessibility, existing facilities and room for expansion.

**Natural system:** The presence of ship wracks, shoals, sandbars and strong tidal currents make it difficult for ships to maneuver in the outer delta. The 'Barra' is caused by the bypassing of sand along the whole coast of East Africa in northern direction. When the sand passes the entrance of the estuary, it is picked up by the movement of the tide. Once out of the main stream along the coast the sand is able to settle down on the bottom.

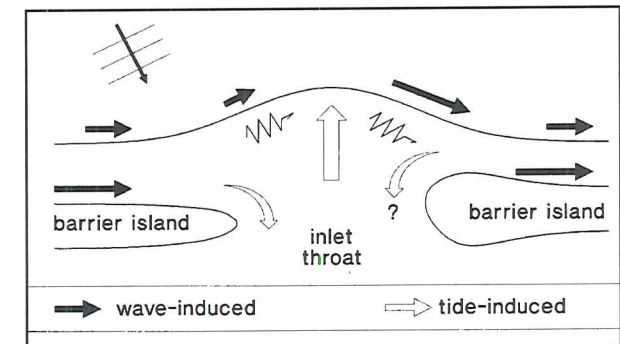
## 1.3. Possible driving forces:

Three different driving forces behind economic development have been determined:

	Strengths:	Weaknesses:	Opportunities:	Threats:
Agri-Industry	Natural resource Labor intensive	Dependent on weather Low value density	Fertile environment Available land	Insects/diseases Extreme weather Lack of infrastructure
Tourism	High margins Low initial investments	Dependence external factors Seasons	Natural competitive advantage WWF Marine park Airport	Current policy No supply industry Lack of infrastructure



Main loop in the Socio Economic system



Schematic presentation of the estuary entrance



Shipwreck in the port of Angoche



Heavy sands	Brings many people & logistics to region High margins Natural resource	Impact environment Profit flows out of region	Scarcity titanium Concession is granted Center of concession area	Inaccessible Radioactivity in soil
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#### 1.4. Possible future developments:

To answer the feasibility question of port development, the following scenarios considering the driving forces are constructed:

**1. 'Perished glorious days':** This means Agri-industry production levels will stay at a moderate level to serve the local consumption market and export will not be developed; fishery will be the strongest sector. The WWF Marine Park plan is rejected by the ministry council and Angoche is no priority area in tourism development. Considering heavy sands, Kenmare Resources will build a new logistical centre near Moma because access to Angoche is very difficult.

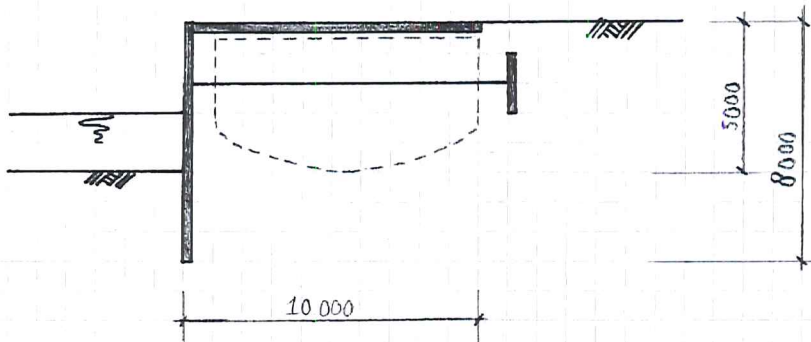
*Cargo flow:* Small industrial fishing will continue and produce/transport about 10 tons per month. Processed cashew will produce about 30-50 containers a year and some other product groups such as timber, coconuts and cassava can generate some incidental demand for transport. Besides that, local merchants transport about 50 truckloads a month between Nacala and Angoche.

*Port development:* The described cargo flow cannot justify a large investment in port facilities. However, to maintain present economic activity and prevent further downfall, some immediate action is required since the current situation at Porto Nova will not last much longer. Advised are minimal adjustments for the port, including a driven, anchored wall of prefab concrete and a spacious work floor of concrete poured in situ.

**2. 'Angoche; hidden treasure':** In this scenario tourism will be the driving force of the economic development in Angoche. The WWF will set up a marine reserve and develop different tourist attractions at Sangage, Praia Nova and some of the islands. Fishery might at first suffer a little from the 'no fishing zone', but will within some years also profit from the renewed supply of fish and prawns. Agri-industry will slowly be able to raise production since they experience positive side effects from the emergence of some supply industry and improvement of the infrastructure. Kenmare will not use Angoche as a logistical node because they can still not access it.

*Cargo flow:* The cargo flow will be the same as in the first scenario, raised with a larger demand for consumer goods. Since agri-industry also experiences positive effects the demand for transport of these products will also rise. The most increase will be found in the demand for transport of people.

*Port development:* In this scenario it is more difficult to defend or reject a larger port development. The cargo flow might rise to a level where a sea connection to Nacala is very interesting and port development



'Minimal design'



Road Nampula – Angoche; keeps tourists away

might be justified. However, because possible users exist of many small parties, economies of scale cannot be established. This makes initial investment and port operation very hard to find. Advised is to make the same arrangements in Porto Nova as in first scenario. Besides that, some minimal facilities to accommodate water access for tourists should be created in the area of the 'Porto Velhor'. Further infrastructural investment should be focused on the road to Nampula.

**3. 'Gateway to Nacala':** This scenario is based on the fact that Kenmare Resources, which has a concession to exploit the heavy sands north and south of Angoche, will establish its logistical headquarters in the town of Angoche. They will use the port to receive all their supplies directly from Nacala. This strong link with Nacala will attract investors to the region and the increased economic activity will have many positive spin off effects. Mainly Agri-industry will benefit from this link to Nacala and will raise production of export products. Tourism development will never really come of the ground. *Cargo flow:* The heavy sands operation will need a steady supply of spare parts, energy and food. The more than 400 people that are involved in the operation will generate a large demand for consumer goods. Roughly estimated this will generate a transport demand for about ten containers a month. Since agri-industry finally has a good link to the outside world, it will demand regular shipping of for example cashew, peanuts, coconuts, cassava and wheat. This is estimated at 15 containers a month. *Port development:* In this scenario large port development is very desirable and justified. The transport demand of the large heavy sand project will function as a motor which can trigger the economic system in an upward spiral. A road is still very desirable, but a port development should be prioritized.

Advised is to build a new, durable quay which can serve for many years. For the dimensioning of the port, an average coastal container vessel is used as Design Ship ( $l \times b \times d = 90 \times 11 \times 4.5\text{m}$ ).

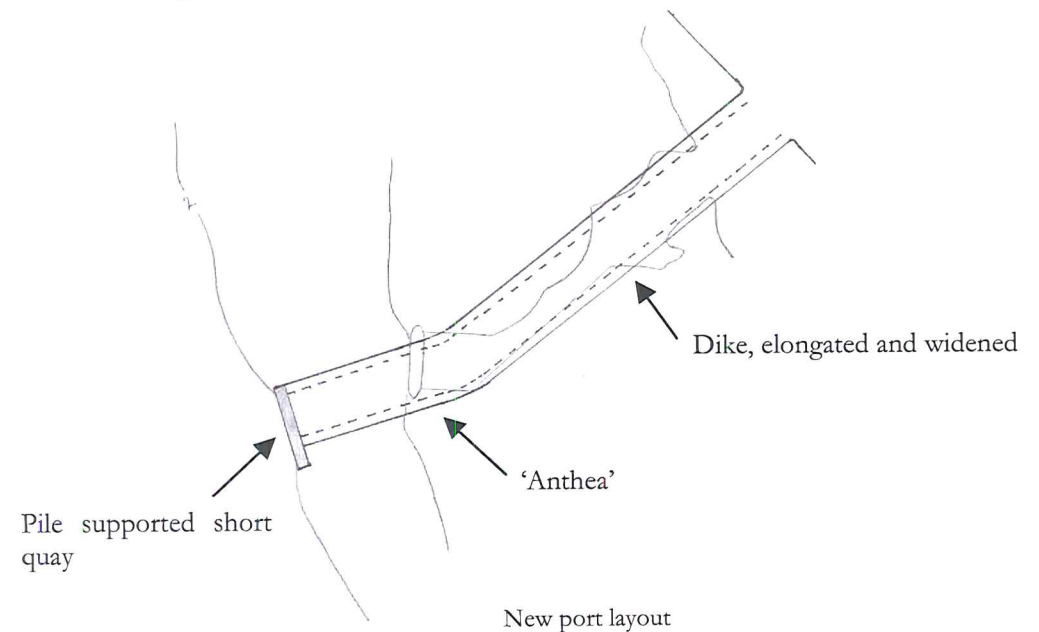
In this scenario an 80 meter pile supported short quay and a dike that connects the pier to the mainland are designed. The structure consists of a timber deck supported by timber piles.

To accommodate the largest vessels mooring dolphins of 20 meter are added on both sides of the short pier. Seeing the presence of weak soil in the mangrove rich area of Angoche, the important advantage of the pile-supported quay is decisive: piles are driven up to the bearing force soil. The piles can be constructed out of concrete, steel or timber. Chosen is to construct the piles in timber, due to its high availability, relatively low weight (advantage during the construction) and relatively low costs.

The existing spit of land at 'Porto Nova' will be widened up to 40 meters and elongated by 100 meters up to the two meter depth line and will be constructed out of natural materials found in the region of the port, such as clay. The pile supported short quay will be positioned parallel to the

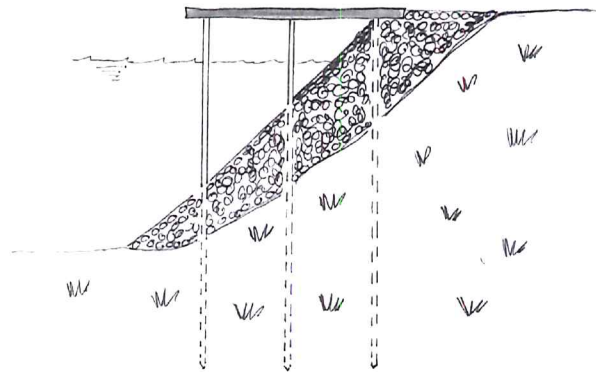


Concession area Kenmare Resources





two meter depth line and no further, whereas the ebb stream and the field of currents will be influenced significantly. To reach the missing required depth, dredging of 3.5 meters is necessary.



Construction on piles

## 1.5. Facing the 'Barra'

At this moment the entrance of the channel which leads to the port of Angoche allows vessels with a maximum draught of 5 meters at high tide. Once the port of Angoche becomes a strong feeder port of Nacala, improvement of the navigability and the possibility to receive larger vessels is desirable. In order to deepen the entrance channel different interventions have been tested on the following criteria: durability, effectiveness, accuracy, possible negative side effects, impact on the environment and availability of materials. The best scoring interventions have been used to construct three different possible solutions which each have their strengths and weaknesses. The solutions are presented below:

### 1. Dredging:

*Explanation:* Dredging out an entrance channel at the desired depth is possible at both routes.

*Positive:* This intervention is very accurate, reliable and delivers a direct result.

*Negative:* Dredging is not very durable and has to be repeated at least every five years. Furthermore the channel is very vulnerable to extreme weather conditions and the depth can disappear at once. The presence of strong currents, heavy sands and ship wrecks can complicate this solution.

### 2. Guiding the ebb stream at Praia Nova:

*Explanation:* Building a solid, submerged dam of dumped rocks, made watertight with clay and sisal mats into the entrance of the estuary at Praia Nova. This will guide the entire ebb stream to flow out through the channel at route 2. This smaller opening will cause the velocity of the stream to be higher which has the following effects: an increase of the depth of the channel, further transport outward of the sand in suspension and a diversion of the bypassing sand stream.

*Positive:* This intervention will create a durable solution and will also protect Praia Nova and Ilha de Buzio of further erosion. During construction a lot of employment will be created.

*Negative:* Results will take one or two years to be visible. At first the currents may even be worse for a while. Furthermore the construction will require a lot of material and has to be very well constructed to resist erosion since it is submerged.

### 3. Decrease sediment in suspension:

*Explanation:* A submerged construction of dumped rocks, parallel at the coast, will prevent breaking waves to reach the coast. Breaking waves in shallow water bring sand into suspension. The construction will decrease sediment in suspension which passes the entrance of the estuary. This will result into retreat of the sandbar and the shoals.

*Positive:* It is a simple construction. Built for route 2, it will also protect Ilha de Buzio.

*Negative:* Results will only show after some time and are not very accurate to predict.



Port of Angoche at low tide

## 1.6. Conclusions

In order to start solving the many problems that Angoche has, it has to build infrastructure to develop economic activity. This research has studied the possibilities for port development. Investment in a port has many advantages over investment in a road, but needs a certain high level of transport demand to be justified. The strengths and weaknesses of both a road and a port are presented below:

	Road	Port
Strengths	Universal use Direct result	Private investment Cheaper transport Durable
Weaknesses	Maintenance Many parties involved	'Barra' Exploitation

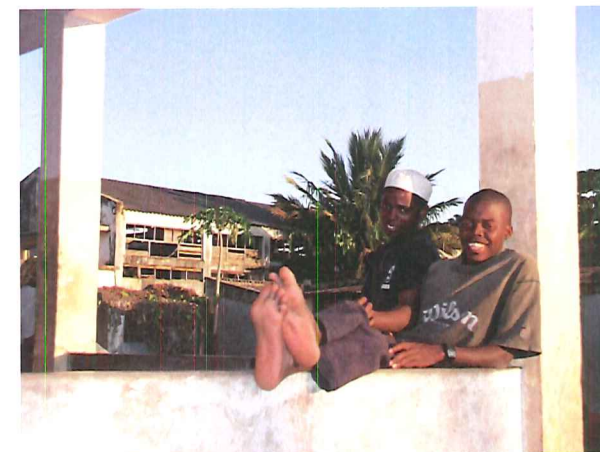
If scenario 3 is within reach, then port development is feasible; the quay can be built and in the nearby future the entrance can be improved. Until the improvement in the entrance, a tidal window can be applied. The research about the obstructed navigability at the entrance of the channel to Port of Angoche has led to three different interventions; dredging, guiding of the ebb stream and the decrease of sediment in suspension. To reach the most effective solution, interventions can be combined. The combination of intervention two and three seems the most promising solution and is advised. The costs of the three different interventions vary a lot: 25-35 million euros for dredging, 10-20 million euros for guiding of the ebb stream and 3-5 million euros for the decrease of sediment in suspension.

Although Angoche might have to be dependent on some external factors for its economy to pick up again, it must not neglect the activities that still exist. Therefore some immediate measures are required to keep at least some access to the sea at the Porto Nova. Furthermore everything should be done to avoid the 'Perished glorious days' scenario for Angoche. This means:

- Minimal repair of the quay at Porto Nova
- Strong lobby for the WWF Marine Park
- Repairing the bridge over the Meluli river between Moma and Angoche
- Improvement of the road between Angoche and Aube



The road has many users



The future of Angoche at the central market





Sunrise at the beach of Maputo

## 2. Recommendations

This report is merely a pre-assessment, providing insight in the most important issues considering the port of Angoche. Therefore research has to be done on the following aspects:

- Which scenario, out of the three distinguished scenarios, is most likely to occur?  
The outcomes will have an impact on the priority of other recommendations.
- The characteristics of the soil of the sea bed in the estuary of Angoche; relevant for the port development.
- The possibilities and impact of an improved road connection to Nampula.
- The possibilities to attract investors.

If the structures recommended in the Natural System part are likely to be build , further research has to be done on: the structure, side effects and sedimentation transport.



People of Angoche



People of Angoche



People of Angoche

## **Part 6: Resources & Maps**





## Resources

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Página de Moçambique,	<a href="http://www.mozambique.mz">http:// www.mozambique.mz</a>
Port of Maputo	<a href="http://www.portmaputo.com">http:// www.portmaputo.com</a>
Nacala corridor	<a href="http://www.nacalacorridor.com">http:// www.nacalacorridor.com</a>
Waterbouw kennisbank	<a href="http://www.kennisbank-waterbouw.nl">http:// www.kennisbank-waterbouw.nl</a>
WWF,	<a href="http://www.wwf.nl">http:// www.wwf.nl</a>

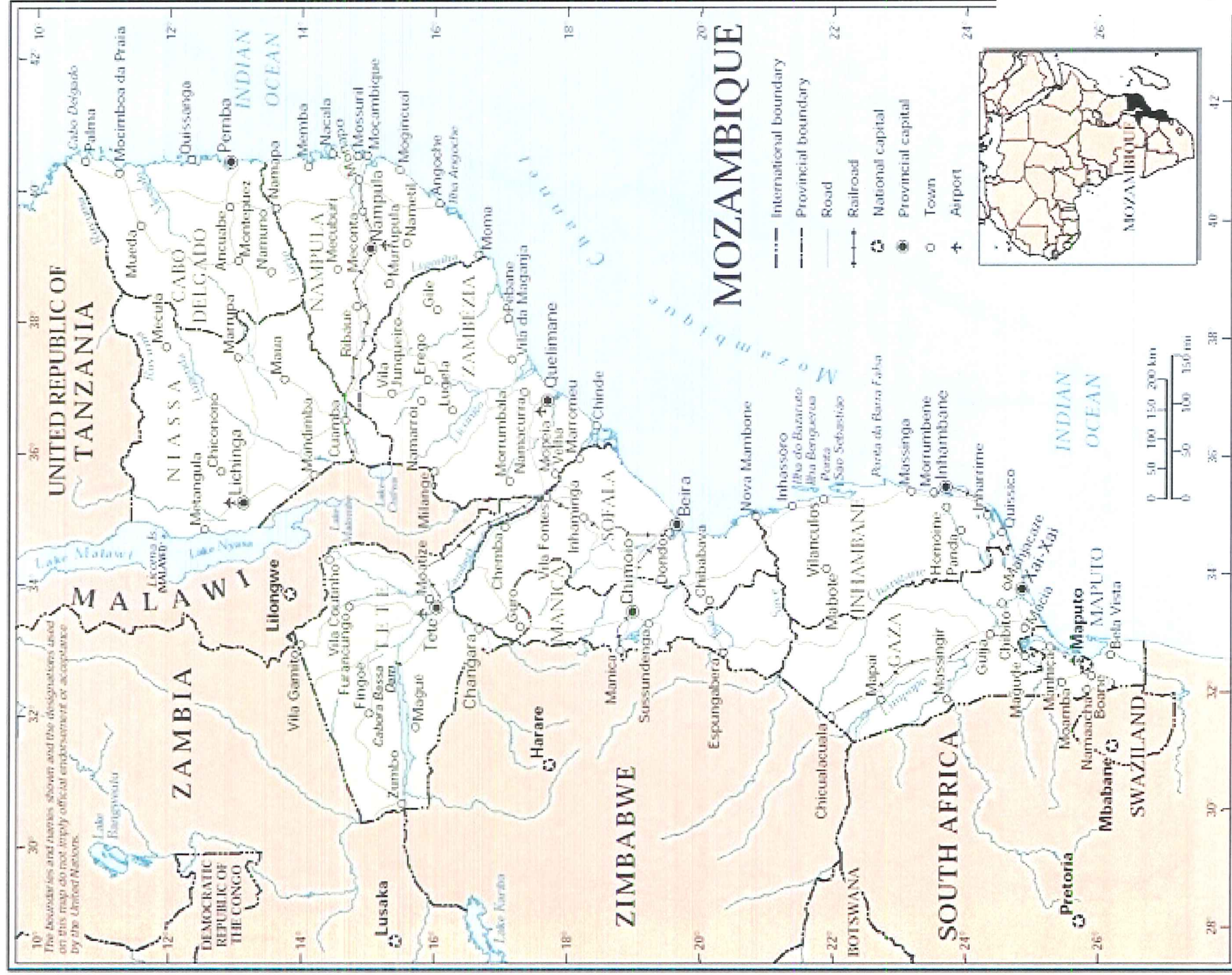
## 2.4. Interviews

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Boston, E.	Employee IMF
Braga, M. T.	First Administrator District of Angoche
Bragança, J.M.	General director Florestal Lda.
Bragança, P. O.	Commercial director Florestal Lda.
Carvalho, P.	Director SNV Angoche
Gorham, J.	Engineer Maputo Port Development Company
Gomes, D.	Commercial director CFM
Gove, A. A.	Director INAHINA

Grand, J. W. le	First secretary good governance Royal Netherlands Embassy
IJssel, W. van	First secretary Environment Royal Netherlands Embassy
Kroes, J.	Local expert, Wageningen University
Local Fishermen	Local experts
Luya, A. M.	General director Mawipi Pescas Lda.
Miranda, A.	General director Miranda Cajú
Mucanheia, F.	Advisor of the governor of Nampula
Mundlovo, E.	Director Ports Ministry of Transport and Communication
Negenman, T.	First secretary Water and Sanitation Royal Netherlands Embassy
Samuel, A.	Director District Angoche of Ministry of Industry and Trade
Schalke, A. J. F.	Agricultural economist Ministry of Industry and Trade
Son, H.	General director Bassopa Securities
Tulliás, J.	Director “O Pescador”
Tulli, E.	Local merchant
Virtuoso, P.	Administrative delegate Navique
Visser, I.	Director Consultoria Tourism
Visser, A. de	Local expert, Wageningen University

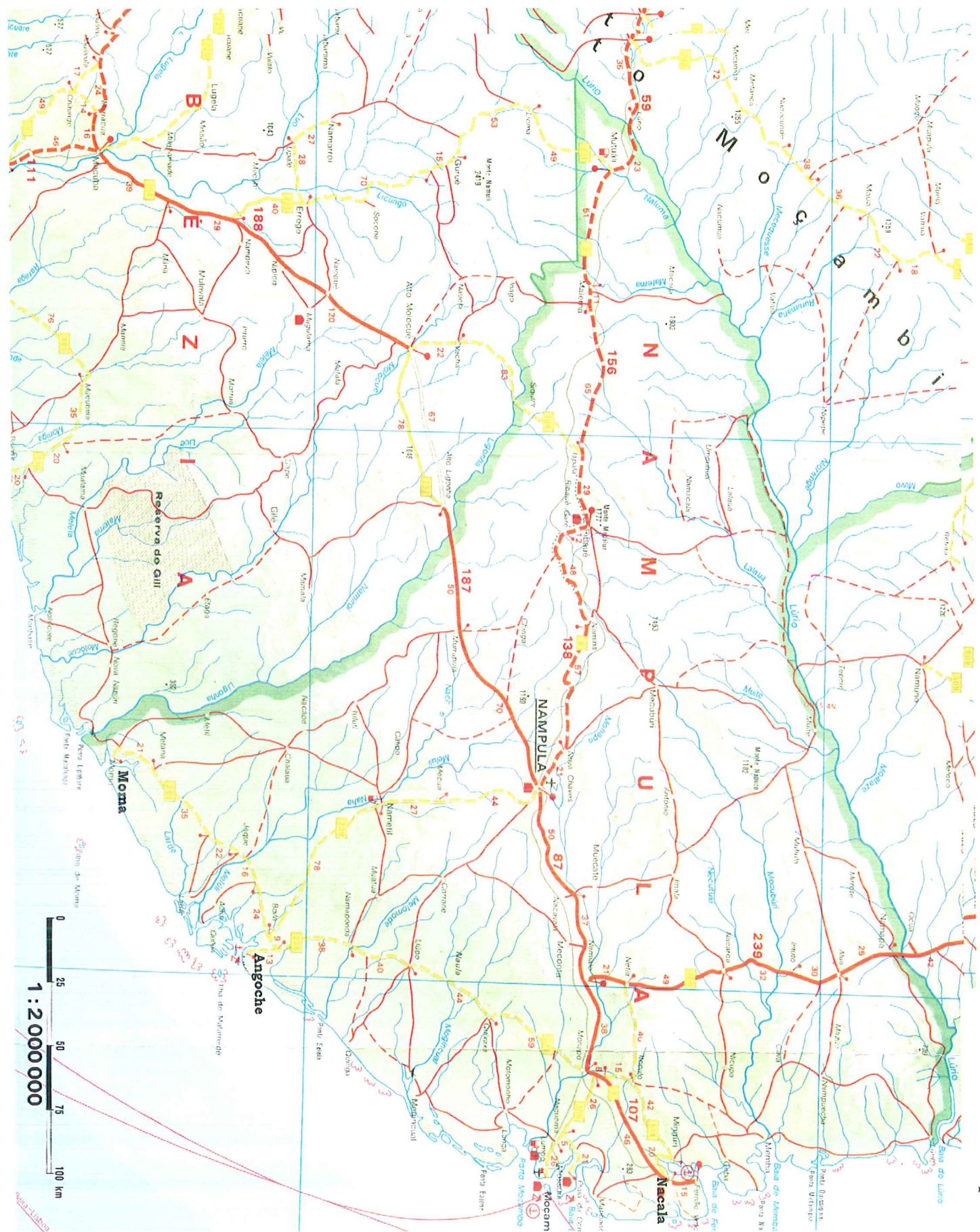


## Maps:

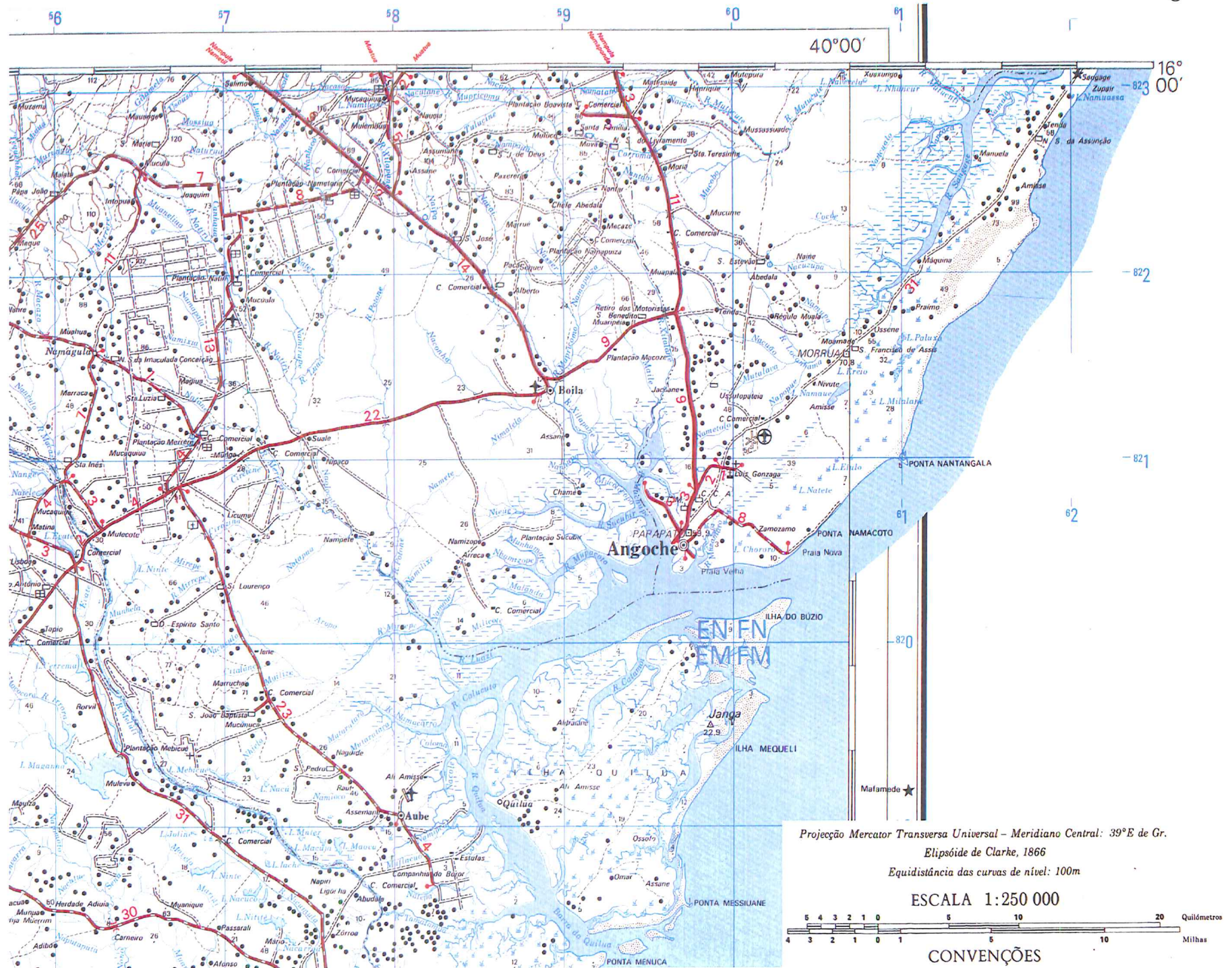




Province of Nampula









MOZAMBIQUE  
ILHA EPIDENDRON  
TO  
PORTO DE MOZAMBIQUE

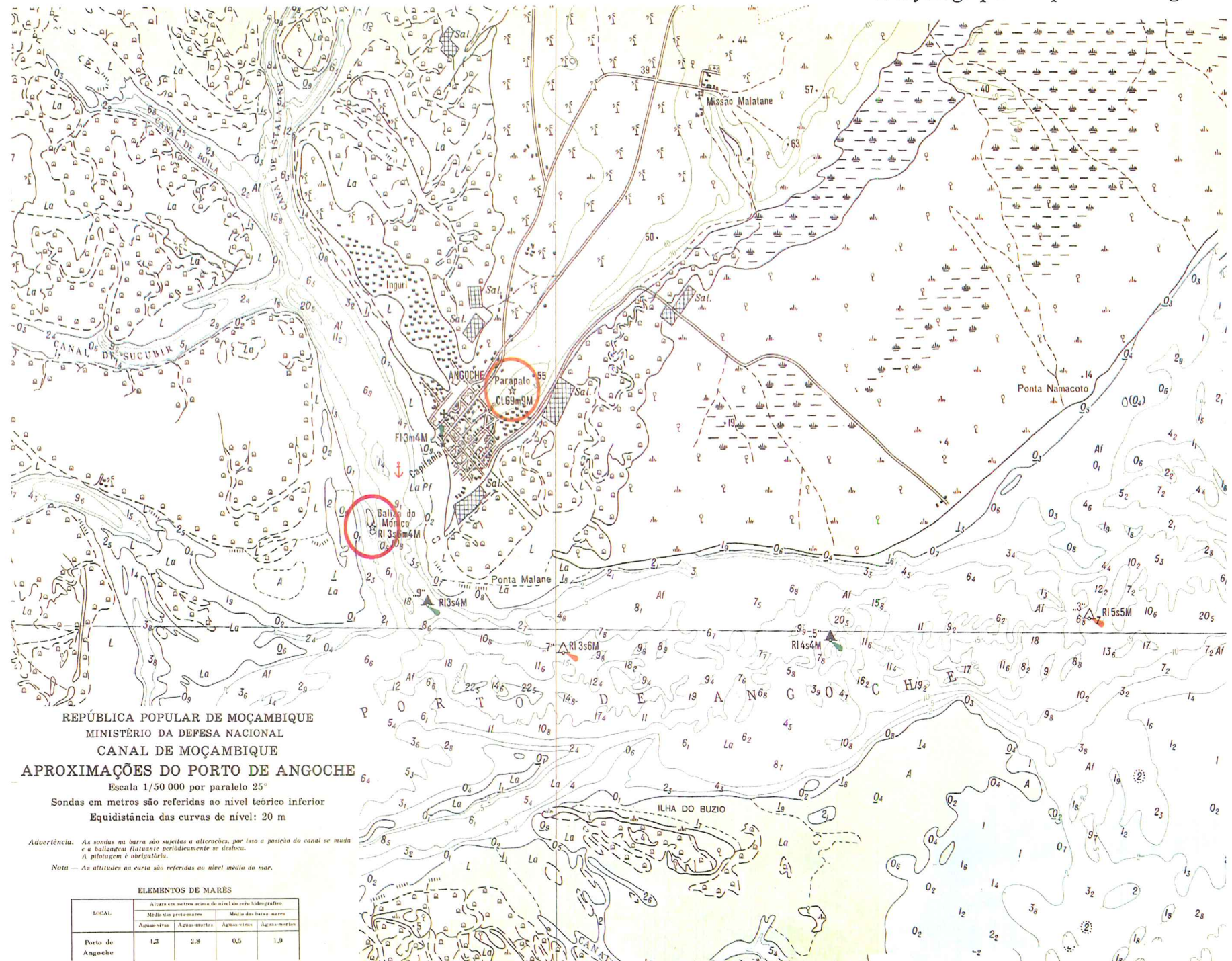
DEPTHS IN METERS  
SCALE 1:300 000 at lat 20°00'

The chart displays the coastal region of Mozambique, featuring the Bay of Vilanculos and the Bay of Inharrim. Key geographical features include Ilha de Angoche, Ilha de Mafamede, Ilha Puga-Puga, and Ilha Miguel. The chart includes depth soundings, navigational aids, and a scale of 1:300,000 at latitude 20°00'.

DEPTHS IN METERS  
SCALE 1:300 000 at lat 20°00'

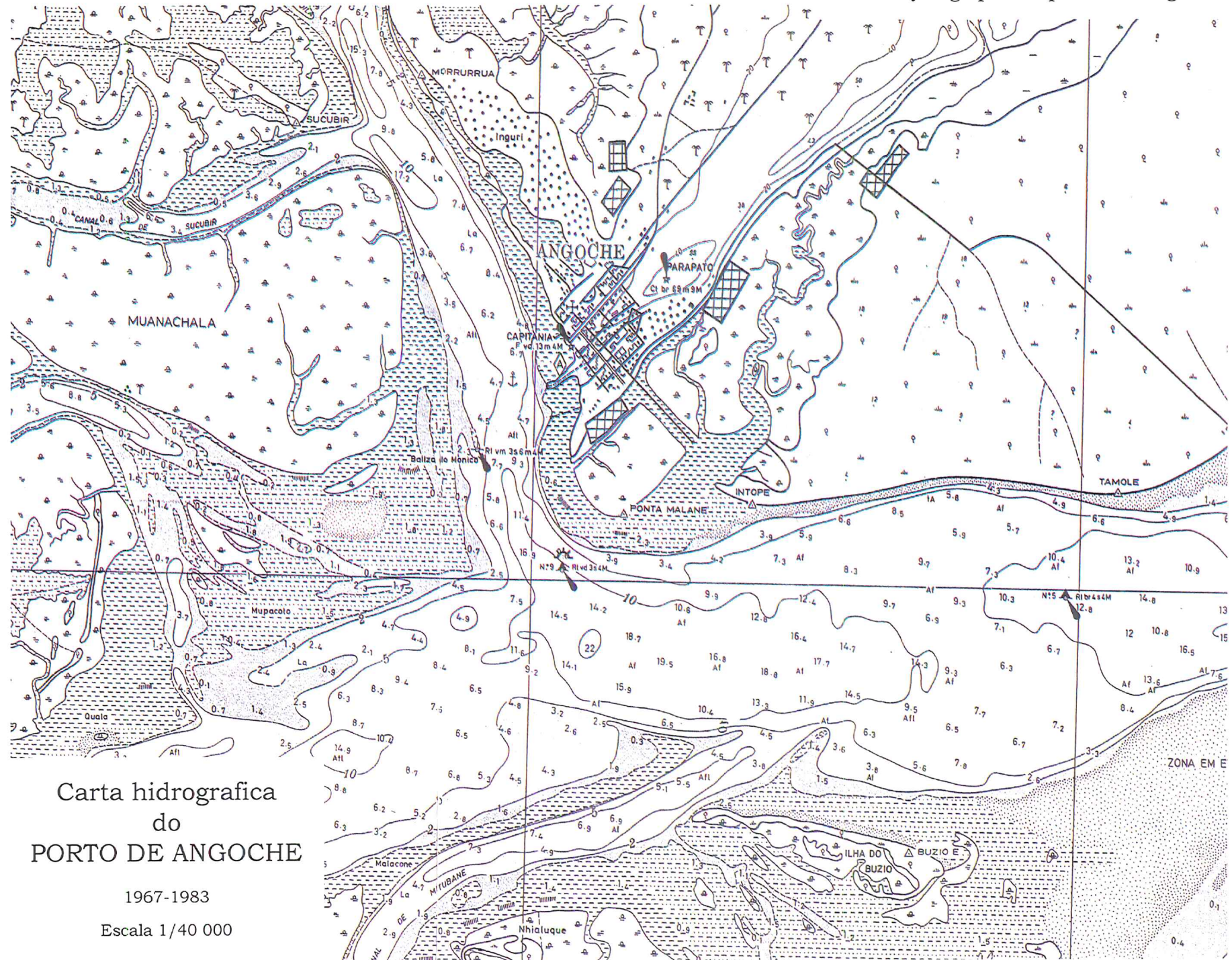


## 2. Hydrographic map - Port of Angoche

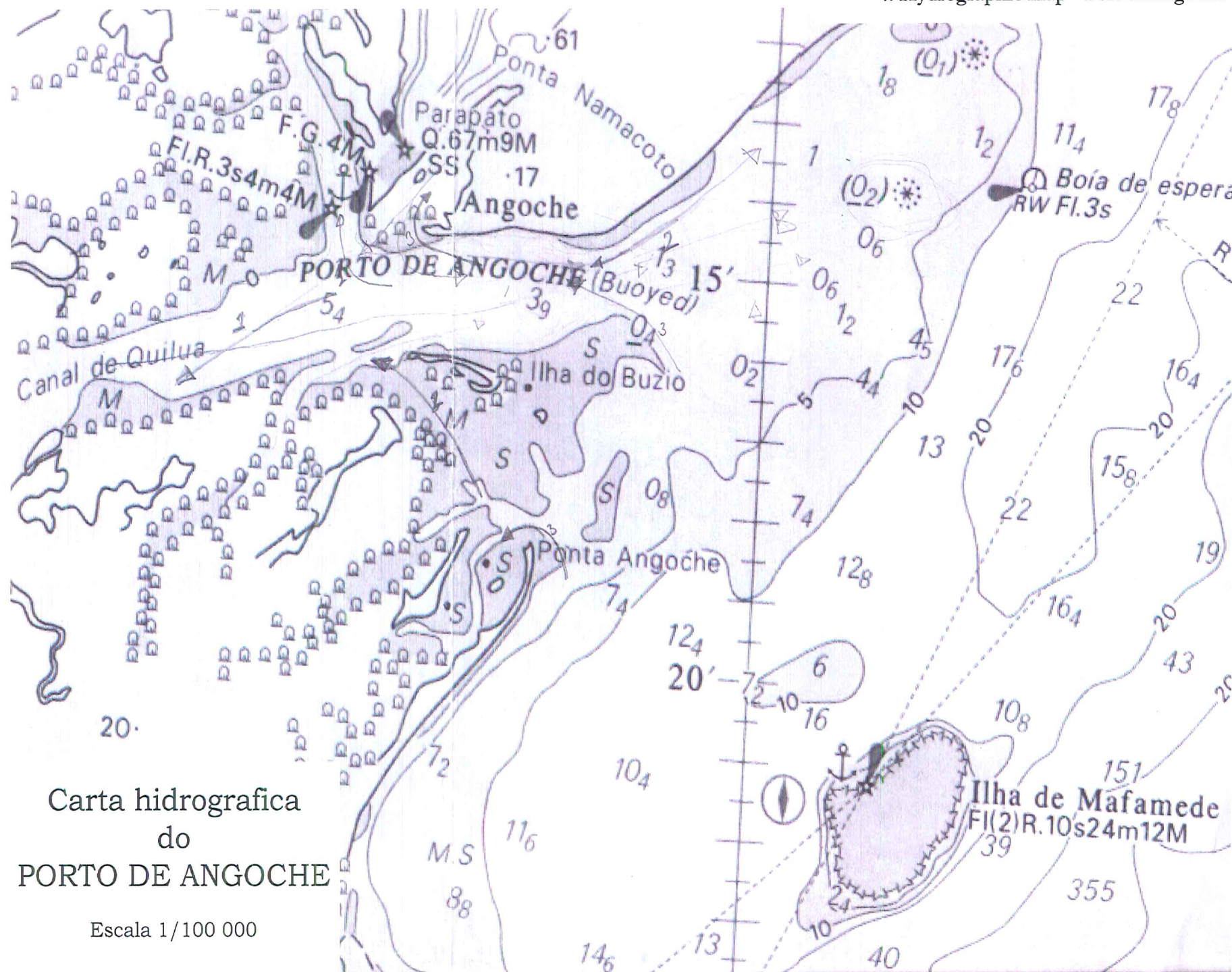




### 3. Hydrographic map - Port of Angoche



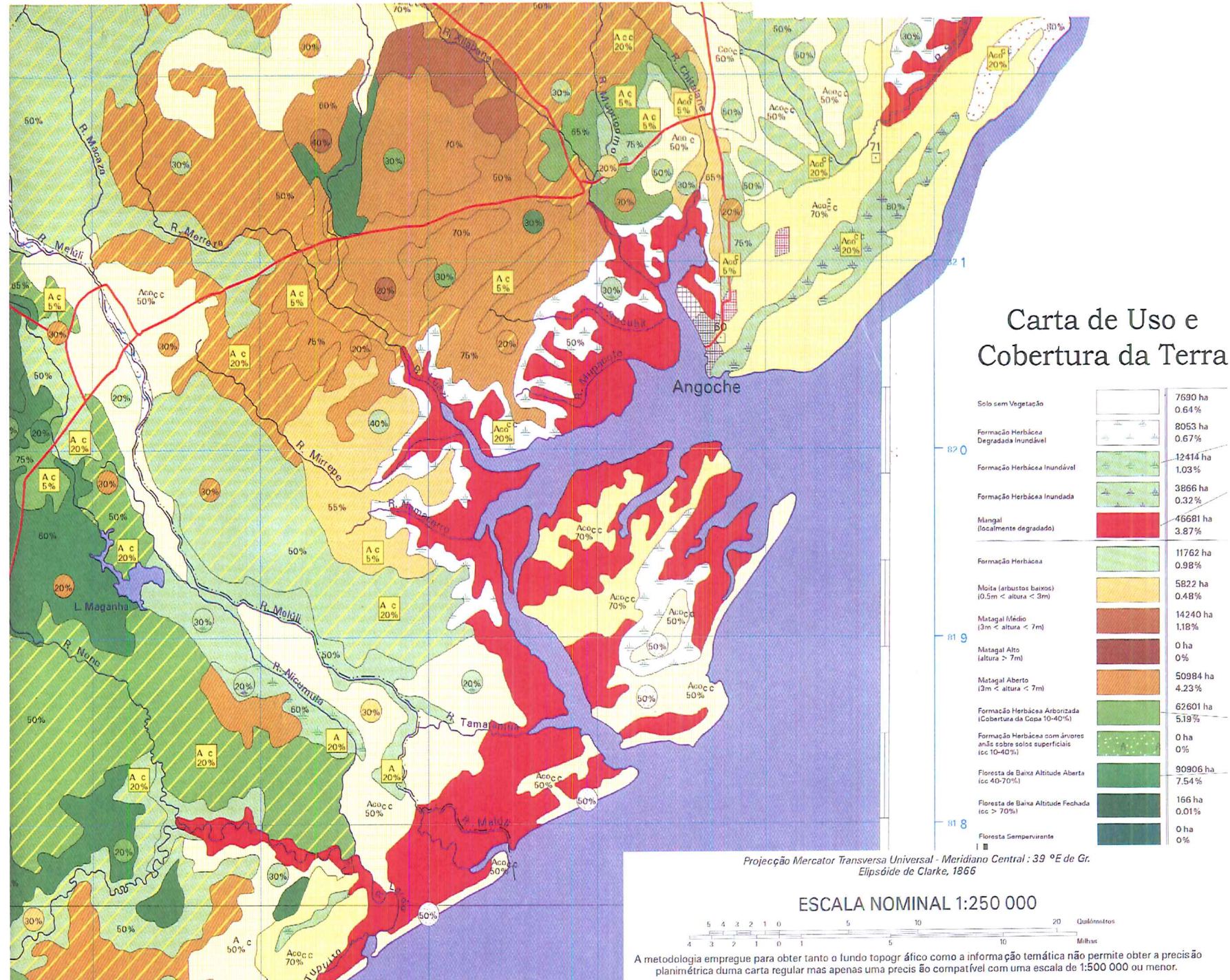




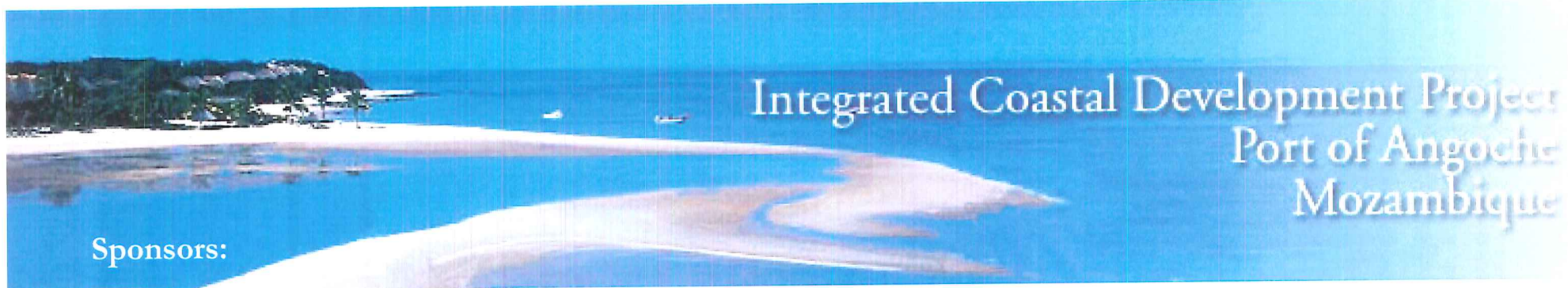
Carta hidrografica  
do  
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Escala 1/100 000









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